NATURAL HISTORY

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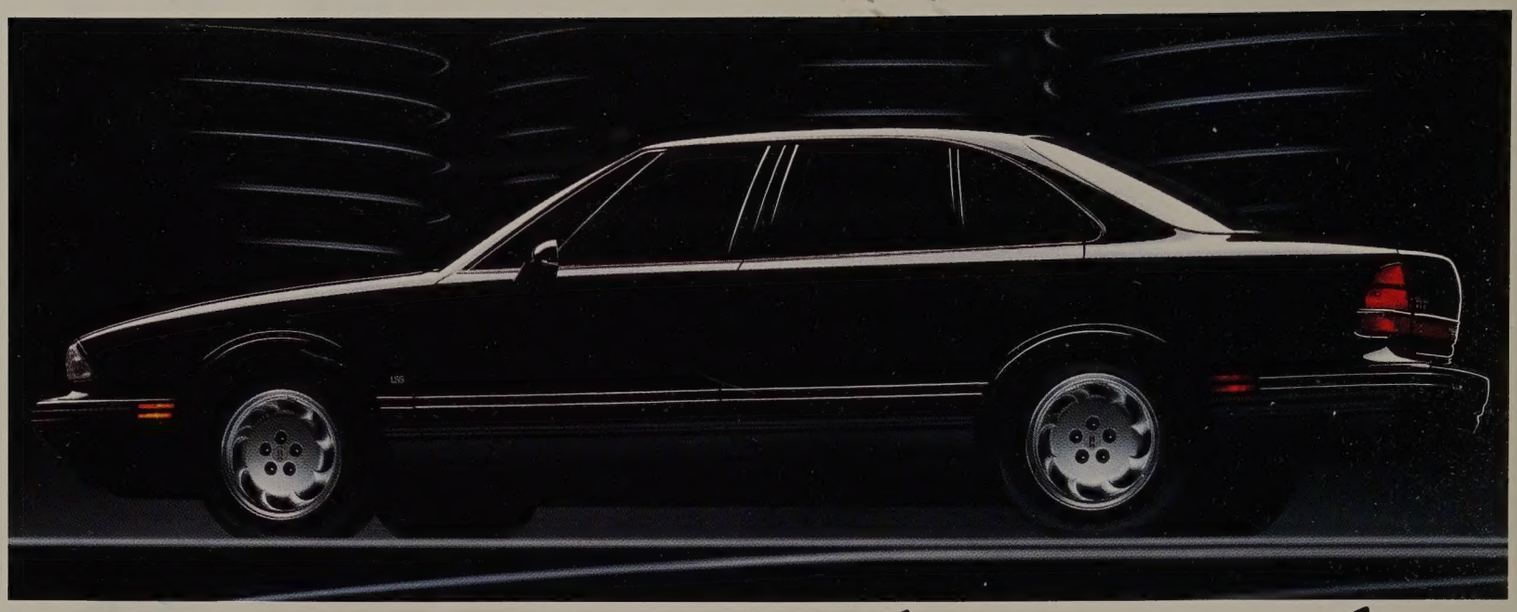

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Bill Montevecchi

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(including explosives) and turn famous battle sites such as Truk Lagoon, where more than thirty Japanese ships were sunk in a few days, into tourist destinations for divers.

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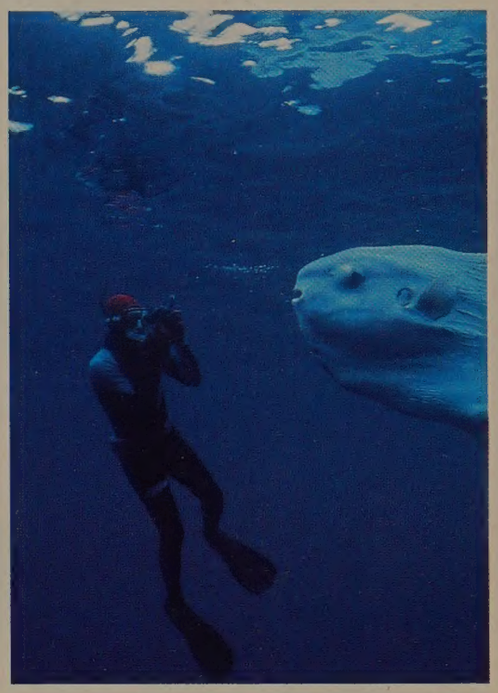
Photographs by Mike Johnson

The gigantic mola, a relative of the puffer, can weigh as much as 5,000 pounds. The disk-shaped fish lacks a true tail and propels itself with its long dorsal and anal fins. It often rests on its side at the water's surface and basks in the sun.



The mola is impervious to most predators, but killer whales, sea lions, and humans take a toll on the gentle giant.

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Howard Topoff

One species of slave-making ants raids other ant nests, drives off the queen and her workers, and steals and rears the brood. The pupae emerge as slaves, foraging for the colony, removing wastes,

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The Vervets' Year of Doom

Lynne A. Isbell

Scientists became alarmed when their study population of vervets, modest-sized monkeys found in Kenya's Amboseli National Park, fell drastically,

disappearing in growing numbers. In addition, the decline was exaggerated by the "Nairobi effect"—more monkeys disappeared each time the researchers left their camp for a few days to visit Kenya's capital city. As with many natural mysteries, the solution has several interacting elements: the behavior of leopards, the century-long cycle of fever trees, and the dangers for territorial monkeys when they must move to strange turf.

and excavating new chambers. Another species of slave-making ants depends on the ability of the queen to invade a foreign colony and kill the resident queen. She gets the workers to accept her as their new queen by covering herself with the perfume of the slain queen. Cuckoos, minnows, and many other creatures have evolved successful parasitic strategies, but slave-making ants are the supreme social parasites.

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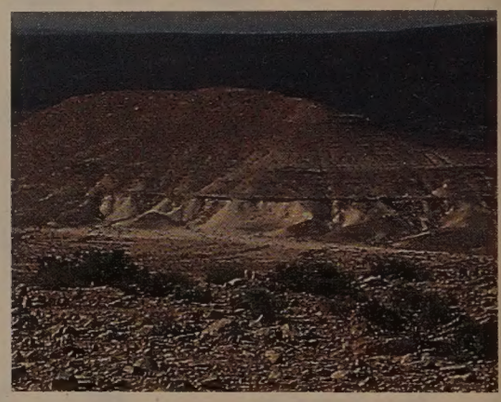
Clive G. Jones and Moshe Shachak

Photographs by Jeffrey L. Rotman

Most snails thrive in cool, moist climates, so researchers were surprised by the extent of the populations of three different snails in the arid highlands of Israel's Negev Desert. Furthermore, these snails graze heavily on lichens and even



eat bare rock by scraping it into fine particles with their tough, tonguelike radula. During the heat of the day, the snails retreat beneath the rocks, where they defecate nutritious pellets that contribute significantly—about 800 pounds per acre per year—to the region's limited soils.

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FOR THE MOMENTS THAT MATTER MOST.

LEVIATHAN LOCOMOTION

In "Hooking Leviathan by Its Past" ("This View of Life," May 1994), Stephen Jay Gould appropriately notes that cetacean evolution required only slight modification of terrestrial locomotor movements in the transition to aquatic propulsion. Mechanically, however, the transition required a major change in the manner propulsive force was generated.

Semiaquatic mammals (such as beavers, muskrats, or river otters) swim by paddling, whereas fully aquatic animals (such as dolphins or seals) oscillate their hydrofoil-like flukes or flippers. The latter method is at least twice as efficient as paddling. Ancestral cetaceans changed from paddling to hydrofoil oscillation probably through the use of a modified underwater gallop. Paddling with the feet while flexing and extending the body—otters do this when they are in a hurry—generates propulsive force by both means. A long tail would enhance propulsion and aid in selection for the more efficient mode. The discovery of *Ambulocetus* strongly argues for this scenario.

Why did pinnipeds (seals and sea lions) differ from cetaceans in evolving the use of flippers instead of flukes? The answer may be that their ancestors lacked the elongated tail so wonderfully exploited by cetaceans and sirenians.

FRANK E. FISH
West Chester, Pennsylvania

KUDOS FOR FOSSIL MAMMALS...

I want to compliment you on the special edition on the rise of mammals ("The Marvelous Mammalian Parade," April 1994). Please give us more. Does that issue signal, I hope, the end of dinosaur-mania?

FRANCIS A. KORNEGAY, JR.
Silver Spring, Maryland

AND A CORRECTION

As a carpenter, I was intrigued by the caption to the right of the opening illustration of "Successful in Spite of Themselves," (April 1994). It refers to glyptodonts' having 200-pound carapaces sixty feet in diameter. If the glyptodonts in the painting are drawn to scale, they are also thirty-five to forty feet high.

With wood prices going through the roof, the domelike carapaces may well be a boon to the housing industry. Two men could easily carry a "Glyptodome" (I've already registered the trademark) large enough to house several families. I won't be fooled by such sly disclaimers as "We really meant sixty inches or six feet." I'm sure there are enough of these things to make us all a bundle.

PHILIP MCDONALD
Saugerties, New York

THE EDITORS REPLY: As noted in our caption, South American glyptodonts "reached giant proportions," and their carapaces did weigh some 200 pounds. Unfortunately, because of a typographical error, we inflated the diameter of this extinct creature's shell by a factor of ten. So, rather than a disclaimer, we offer an apology to the author, David Webb, and to our readers. While a disappointment to carpenters, the news may be of interest to plumbers. Webb says that "some families in fossil-rich parts of Patagonia have used the shells as bathtubs."

IS THE RAIN FOREST REALLY A MEDICINE CHEST?

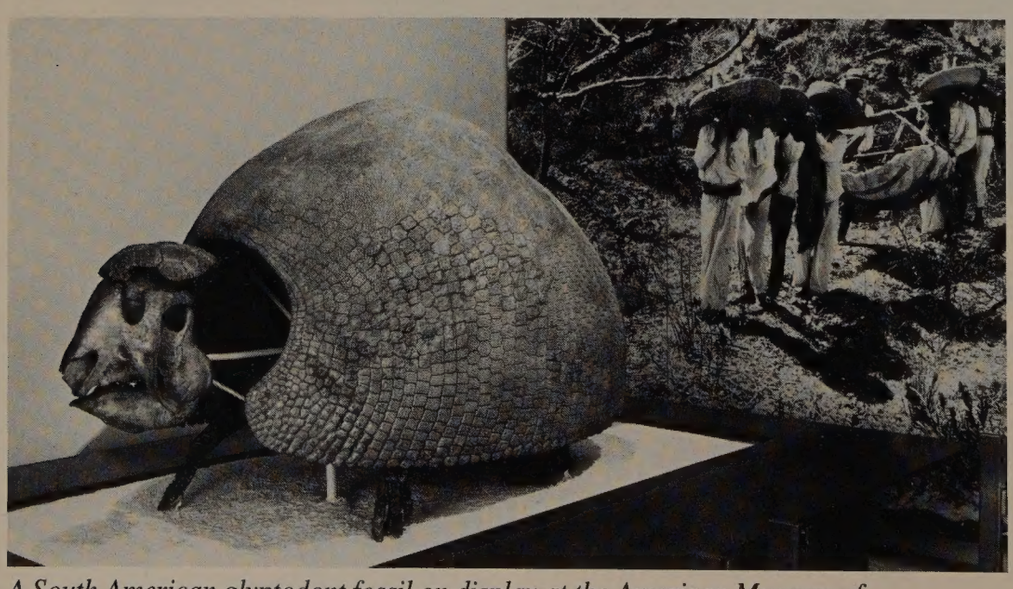
In his review of Mark Plotkin's "Tales of a Shaman's Apprentice" ("Reviews," March 1994), J. Worth Estes downplays Plotkin's (and other ethnobotanists') claims for the pharmacological value of "the nearly infinite variety of plants" to be found in the rain forests. Estes writes, "I have found no convincing evidence that untold numbers of valuable medicines await us in the Amazon basin."

Yet Foster and Duke in *Field Guide to Medicinal Plants* (Houghton Mifflin, 1990) cite numerous native and rain forest plants currently used for medicinal purposes. They note that China and India are both "prime example[s] of 5,000-year-old...medical systems that are constantly vindicated."

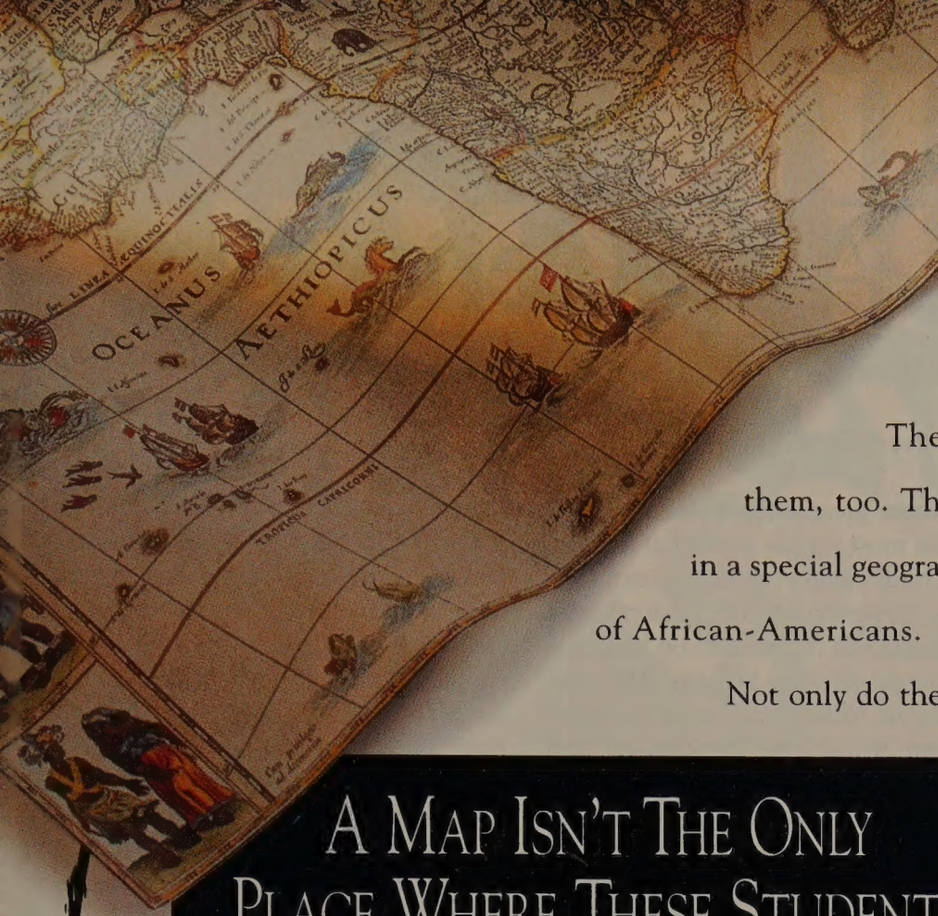
Are we to believe the ethnobotanists or the pharmacologist?

JAMES E. WILKINSON
Barre, Vermont

J. WORTH ESTES REPLIES: I have not seen the book Mr. Wilkinson cites, but I have seen many like it, including a number that were originally published in China. Save in the relatively few instances in which plants have yielded valuable drugs (e.g., digitalis, atropine, and penicillin), such books often ascribe medicinal values to plants on the basis of anecdotal data alone. The most common such claims state only that the plant is "used" by a given population to treat some condition. These books do not cite supporting evidence of the kind that pharmacologists and physicians need to have in hand before they can conclude that any drug provides truly effective therapy (however efficacy is assessed) for some specified illness. I did not write that there are *no* drugs waiting for us to find them in the rain forests of the world—indeed, the National Cancer Institute has just launched a massive search for therapeutic natural products. I only argue that we have precious little evidence that they are there.



A South American glyptodont fossil on display at the American Museum of Natural History. Carapaces could be as large as six feet in diameter.
J. Beckett and Denis Finnin; AMNH



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The Great Auk Cemetery

How a tiny North Atlantic island became the main burial ground for an entire species

by Bill Montevecchi

For decades now, I have returned each summer to the seabird capital of the North Atlantic, a desolate, foul-smelling, surf-pounded mass of granite, known as Funk Island, off Newfoundland's northeast coast. On this "marvelously terrible place," as a local skipper calls it, I have studied the colonies of gannets, murres, and puffins that help me monitor ecological changes in the ocean. But as I study the living birds, I cannot ignore the constant presence of a ghost species: the extinct great auk, once known (inaccurately) as "the penguin of the North Atlantic." Funk Island once contained as many as 200,000 of these magnificent seabirds, and its very soil is made of their decomposed carcasses. This year marks a somber anniversary—it was 150 years ago that humans wiped out the last survivors of this species.

A relative of the razorbills and puffins, and about the size of a small goose, the great auk was black-bodied with a white underbelly, and walked erect, like a penguin. A large, oblong white spot marked the space between its eyes and powerful bill. Although flightless, great auks could "fly" rapidly and gracefully underwater, where they fed on capelin and bottom-dwelling fishes, such as lumpfishes. These auks were also capable of making long sea journeys, and spent much time on the Grand Banks of Newfoundland. Auks were so numerous there that they were depicted in eighteenth-century editions of *The English Pilot*, a guide to North American waters, as indicators to navigators that the Grand Banks were near. At one time the great auk population was so large that most people scoffed at the idea that the birds could ever become extinct.

Auks, however, had the misfortune of being docile and defenseless on land, and much sought after by humans. Millenniums before Europeans came to Newfoundland, Native Americans hunted great auks and collected their eggs, as we know from the quantities of bones and eggshells in paleo-Indian middens. Great auks also held spiritual significance for early aboriginal Americans, and large numbers of auk beaks have been found interred in human graves at the cemetery of Maritime Archaic Peoples at Port aux Choix on Newfoundland's Great Northern Peninsula.

One of the earliest documentations of Funk Island comes from a chart prepared by Pedro Rinel, who was associated with Gaspar Corte-Real's New World exploratory cruise of 1500. Rinel's chart indicates an "Y. dos Aves," or "Island of Birds," near the location of Funk Island. In one of the very first estimates of North American seabird populations, a sixteenth-century observer named Sir Richard Whitbourne thought that the Funk Island auks "multiply infinitely." "God made the innocencie of so poor a creature to become such an admirabel instrument for the sustenation of man," he wrote.

In 1534, Jacques Cartier was among the first European explorers to land there, and he loaded several barrels of salted great auks aboard his ship before continuing his voyage. The birds proved so delectable that Cartier sailed directly to Funk Island the following year, before making his way to the Gulf of Saint Lawrence. "In less than halfe an hour," he wrote, "we filled two boats full of [auks], as if they have bene stones, so that besides them which we did eat fresh, every ship did powder and salt five or sixe barrels of them." Raids on the island to stock ships' larders continued for more than four hundred years. Fresh food supplies became quickly depleted on long ocean voyages, and by the time vessels crossed the Atlantic their crews and passengers were hungry for fresh protein. Near the journey's end, a quick stop at one of Newfoundland's seabird rookeries, particularly Funk Is-

The great auk, or "penguin of the North Atlantic," was hunted to extinction 150 years ago.
From *Extinct Birds*, by Walter Rothschild; AMNH

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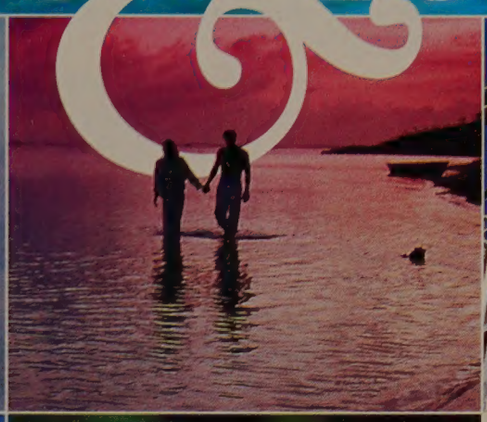

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land, became a necessity. In this respect, Funk Island may be regarded as the New World's first fast-food takeout.

The use of great auks for mariners' fare, however, did not dent the species' prolific population nearly as much as the subsequent mass slaughters to obtain feathers, fat, and oil. During the second half of the eighteenth century, crews lived on Funk Island all summer to gather tons of feathers. "As the birds could not fly," according to one eyewitness report, "the fishermen would surround them in small boats and drive them ashore." There the birds were herded into stone corrals, then thrown live into caldrons of boiling water, plucked, and cast aside. Their feathers became the basis of a mattress and puff pillow industry. Oil was extracted for fueling lamps. As there was no wood on the island, thousands of the auk's fat-laden bodies were used to feed the fires under the great boiling pots. Thousands more were simply thrown into a rocky field, where they eventually composted into the rich soil that supports the island's only grassy area.

Apparently, the auk's lack of flexibility in its breeding habits contributed to its extinction. Great numbers of them were attracted to very few breeding places. Auks built no nests, and usually laid a single egg on bare rock. Maine and Labrador had plenty of suitable breeding grounds, and some ornithologists have speculated that if the bird had bred in small colonies scattered along this wide expanse of territory, instead of in a few island rookeries, it might have survived. On the other hand, there is evidence that they once occupied a much wider range, even including the coasts of Maine and Massachussetts, and were driven to a few remote, rocky islands by relentless overexploitation.

As early as 1785, Capt. George Cartwright sounded an unambiguous warning. "It has been customary of late years," he wrote,

> for several crews of men to live all summer on [Funk] island for the sole purpose of killing birds for the sake of the feathers, the destruction which they have made is incredible. If a stop is not soon put to that practice, the whole breed will be diminished to almost nothing, particularly the penguins [auks]: for this is now the only island they have left to breed upon: all the others lying so near the shores of Newfoundland, they are continually robbed.

By the early nineteenth century, magistates at Saint John's prohibited further taking of auks and eggs, on penalty of public floggings for offenders. Nevertheless, the ban came too late to save the auks, which perhaps had already passed their point of no return.

The last two known great auks were killed on June 3, 1844, on a rocky islet off southwest Iceland. Visitors to Funk Island in the late nineteenth century found huge piles of great auk bones, and small populations of nesting seabirds of other species. About 1860, a vessel removed a load of auk remains to be used as farm fertilizer in the countryside around Boston, Baltimore, and New York.

Huge collections of great auk skeletal fragments have made their way into various museums around the world. Yet some 200-year-old remains of the birds can still be found on Funk Island. Atlantic puffins have burrowed into the peaty soil and established a breeding colony of some 2,000 pairs on the island. Every now and again a great auk bone is kicked outside a burrow entrance by a puffin enlarging a subterranean nest site. About fifteen years ago, I began searching for great auk bones, and soon gathered almost enough to begin constructing a skeleton. Eventually, with the generous help and expertise of several zoologists (and a few key bones from Funk Island that had found their way into the collections of Harvard's Museum of Comparative Zoology), we re-created the first complete skeleton of the great auk in Canada. It is now housed in the Centre for Newfoundland Studies at Memorial University of Newfoundland. While an admittedly futile gesture, it helped me feel that we were trying to make amends for past crimes against the seabirds, and had at least restored one great auk to its home.

Each summer, I return to Funk Island, studying living seabirds to assess the health of the world's oceans. As the most visible, most accessible, and widest-ranging biological indicators of the marine environment, they offer much information to a scientist. However, I also feel deeply protective toward these birds of the ocean. I understand their ultimate fragility and how vulnerable they are to human-induced pollution, disturbance, and overfishing. On Funk Island, the lessons and spirits of the great auks are an ever present reminder that I study living birds in the midst of the great "penguin" cemetery of the North Atlantic.

From the air, Funk Island's gannet colony appears as a white area, while the green patches are grass growing from the composting remains of thousands of great auk carcasses.
Bill Montevecchi

Bill Montevecchi is a professor of biology and psychology at Memorial University of Newfoundland, where he also chairs the biopsychology program. With L. M. Tuck, he co-authored Newfoundland Birds *(Cambridge: Nuttall Press, 1987).*

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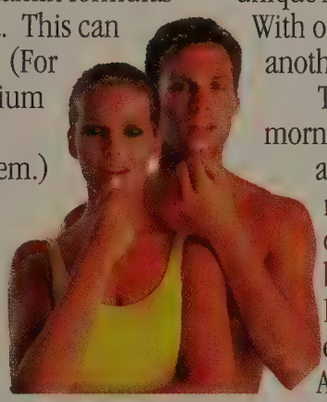

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Happy Thoughts on a Sunny Day in New York City

Scientific curiosity kills the cynic

by Stephen Jay Gould

Galileo described the universe in his most famous line: "This grand book is written in the language of mathematics, and its characters are triangles, circles, and other geometrical figures." Why should the laws of nature be subject to statement in such elegantly basic algebra? Why does gravity work by the principle of inverse squares? Why do simple geometries pervade nature—from the hexagons of the honeycomb to the complex architecture of crystals? D'Arcy Thompson, author of *Growth and Form* and my earliest intellectual hero (along with my father and Charles Darwin), wrote that "the harmony of the world is made manifest in Form and Number, and the heart and soul and all the poetry of Natural Philosophy are embodied in the concept of mathematical beauty." Many scientists, if only to coin a striking metaphor, depict a creating God as a mathematician from the realm of Plato or Pythagoras. The physicist James Jeans wrote: "From the intrinsic evidence of his creation, the Great Architect of the Universe now begins to appear as a pure mathematician."

But much of nature is messy and multifarious, markedly resistant to simple mathematical expression (at least before fractals gave us a way to formulate the complexities of a mountaintop, a coastline, or a leaf). And other scientists have developed equally striking metaphors about a creator who revels in the unquantifiable details—as in J. B. S. Haldane's famous quip (see my column of January 1993) that God must have an inordinate fondness for beetles.

We have, in many respects, been oversold on the mathematical precision of nature. Even the preeminent field for abstract, quantified beauty—a domain whose very name, celestial mechanics, seems to evoke ethereal harmony—includes ever so many awfully messy and downright inconvenient irregularities. Why, for example, couldn't God have arranged some simple and decent proportionality between the earth's axial rotation and solar revolution. Why didn't he give the year a nice even number of days, without elaborate fractions that demand complex seat-of-the-pants corrections in our calendars. Why 365 days and almost (but not quite) an extra quarter?—so that we have to add a leap day every fourth time round, but remove it again every hundred years (because God ordained a little less than an extra quarter after 365), except for every four hundred years when we put it back again. (And thus, if you penetrated that sentence, you will grasp why 2000 will be a leap year, even if, among some purists, it will not make a millennium.)

Nature also mocks our attempt to encase her in a Platonic straitjacket by establishing an almost laughably fortuitous reason for some apparent, highly visible regularities that have played a major role in human history. In my favorite example, much discussed by many commentators, solar and lunar eclipses produce a gorgeously precise and tight fit (as the moon's shadow snugly covers the sun and vice versa). Must not such exactitude be explicitly arranged, or at least arise as a predictable consequence from one of those mathematically elegant laws of nature? But the effect is only a happenstance of history. The sun's diameter is about 400 times larger than the moon's. But the sun is also about 400 times more distant—so their disks appear the same size to an observer on earth. (Now consider how much of human mythology rests upon an image of two guardians, intimately related by their common size: "And God made two great lights: the greater light to rule the day, and the lesser light to rule the night.")

When nature so mocks us, she often comes clean every once in a while, as if to offer confession for such a sublime joke. On May 10, 1994, a rare form of solar eclipse, far less spectacular than the conventional lid of darkness, but immensely fascinating for its own more subtle strangeness, enveloped much of North America. The moon's distance from the earth varies quite a bit during its revolution (planetary orbits are also not so regular as the charts in our high-school textbooks implied). If a solar eclipse occurs when the moon lies at maximal distance from the earth, then the lunar shadow does not fully cover the sun's disk. At totality, therefore, a ring of bright light remains at the sun's periphery. Such eclipses are called annular, from a Latin word for ring. (Annular eclipses are much less spectacular than total eclipses at normal lunar distances, for a ring of bright sunshine still yields substantial light—as much or more than on an ordinary cloudy day—while the sky turns off as if God threw a light switch when the moon's larger disk fully covers the sun.)

Don't you wish we could just do this to CFCs.

In a way we can—if we cool our buildings with natural gas.

Natural gas absorption cooling equipment cools with water, rather than with CFCs, which deplete the ozone layer.

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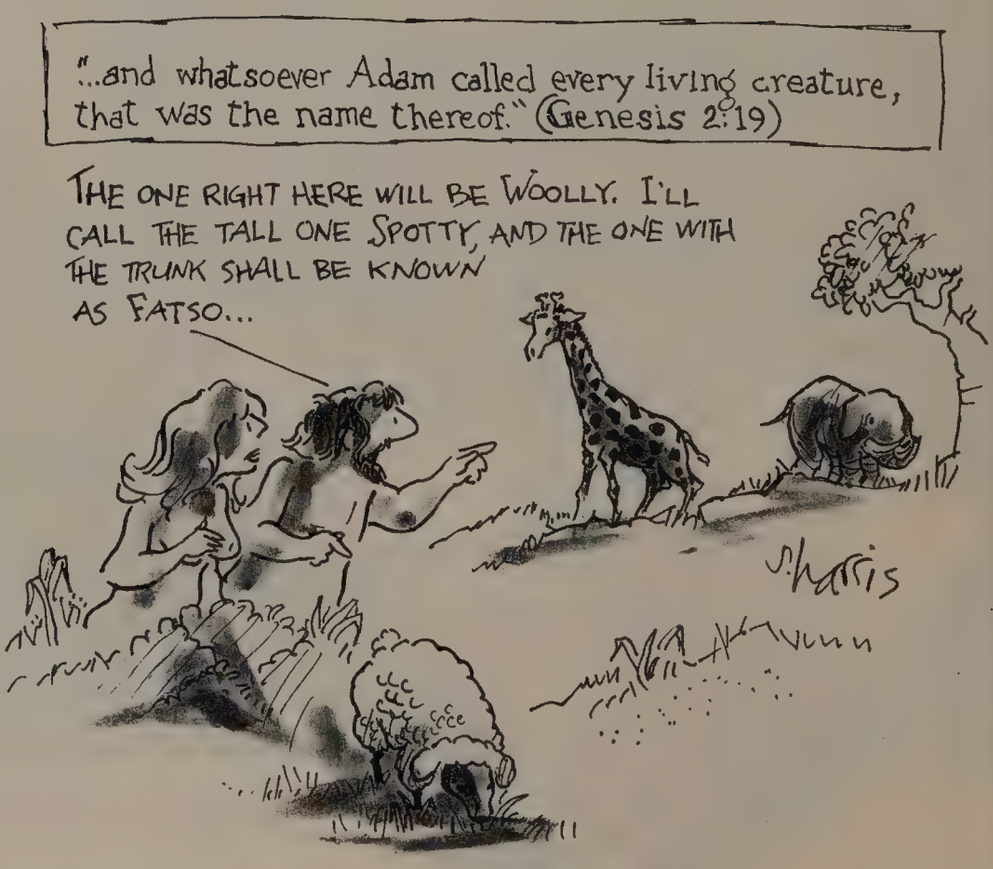
I was angry with myself on May 10. The eclipse was 88 percent complete at my Boston home, while totality beckoned only an hour or two north at Concord, New Hampshire, and many other pleasant sites throughout New England. The next annular eclipse in New England will occur July 23, 2093, long past my watch—so it was May 10 or never (at least without substantial travel) for me. I ordered all my students to drive into the region of totality on pain of instant expulsion. (Professors—reveling in these odd moments of surcease from Shaw's observation that those who can, do; while those who can't, teach—really do enjoy such application of limited power. I so ordered, and not a one of them went—to their eternal shame, but otherwise without consequence.) Meanwhile, duty bound to honor a commitment made before I heard about the eclipse, I went south to New York City, toward less solar coverage by an already compromised lunar shadow.

Many things keep us going through this vale of tears—a baby's smile, Bach's B Minor Mass, a decent bagel. Every once in a while, as if to grant us the courage to go on, the powers that be turn one of life's little disasters into a bit of joy or an episode of instruction. The Lord of the (Partial) Ring must have been smiling on me this May 10, for he brought me in a sour mood to my natal city of New York and then rewarded me with a better experience than totality in Concord could ever have provided.

I love pristine nature, but I am a humanist at heart, and I revel more in complex interactions between fellow members of *Homo sapiens* and the great external world. Now think of every stereotype you hold about New Yorkers. (They are untrue, of course, but culturally powerful as a recognized type or icon nonetheless.) New Yorkers are harried, self-centered, cynical, rushed, acquisitive, incurious, uncommunicative, and downright nasty to all humans who cannot be wheedled or manipulated for material gain. Right? Of course, as all Americans know, even those who have never been east of the Mississippi! A solar eclipse must therefore rank as the last thing that could ever intrigue a real New Yorker. I mean, gimme a break, Mister. You want me to stop what I'm doing and look into the sky—at a partial and annular eclipse? Get lost—and screw in your own light bulb.

Yet, as Joshua once stopped the sun over Gibeon, New York City returned the compliment on May 10. In midtown Manhattan, in the middle of a busy working day, New York stopped to watch the sun.



Let me not exaggerate. Many folks just went on about their business, as the human tide of midday swept down Seventh Avenue. But large knots of eclipse watchers also stood their ground on every street. What was it about this less spectacular form of the general phenomenon—partial and annular, rather than total and completely covered—that could have inspired the interest of New Yorkers? Consider two aspects of this remarkable event.

First, in this age of artificially induced, full-body shake-me-ups, from roller coasters to all the electronic powers of film, video games, and amplified sound, we hardly think that anything so subtle, albeit pervasive, as the character of surrounding sunlight could move our passions or even invite our notice (but then the impressionist painters did have some insights about the power of light's quality). It does not get very dark when the sun is occluded by 80 percent on a bright day; an ordinary cloud cover reduces visibility by more than this. Thus, the sky did not darken precipitously over New York on May 10. But we are exquisitely sensitive to the usual character of light, even though we may not explicitly credit our awareness and may not be able even to state what feels so odd.

It did not, I repeat, get very dark over New York, but the cloudless sky implied brightness, and the day turned eerily somber, while sunlight continued to reign—and people noticed, and trembled ever so slightly. "Moses and the children of Israel" sang a song to God to praise the stunning power of altered celestial events: "The people shall hear and be afraid…the dukes of Edom shall be amazed; the mighty men of Moab, trembling shall take hold upon them…they shall be as still as a stone" (Exodus, chapter 15). And so New York, mightier by far and incomparably more sophisticated than these old kingdoms of the Middle East, noticed and stood still as a sky full of daylight darkened to the level of a clearly nonexistent thunderstorm. A woman said to her friend: "Holy shit, either the world is about to end, or it's going to rain—and it sure as hell ain't gonna rain."

Second, the sight of a crescent sun is so unusual, so outside our daily experience, that people do pause to notice, and wonder. If the first phenomenon, eerie (if slight) darkness, impelled a kind of visceral attention, the crescent sun, by contrast, provoked a more intellectual response.

At every eclipse, official purveyors of the news deluge us with warnings about

grave dangers to our sight should we stare at the eclipsing sun. Don't look up, even for a moment. The sun will burn a painless hole in your retina faster than masturbating boys went blind in the bad old days of dire warnings. I do understand why such exaggerations must be presented. Staring at the sun for minutes on end is a very bad idea and can have all the consequences stated in eclipse warnings—so news sources must say "don't look at all" in order to impart sufficient fear for preventing these longer starings. So strident are these warnings that many people actually come to believe in a special power of eclipse light to do such harm. But one can, of course, look directly at the sun for a moment without danger on all days, both regular and eclipsed. After all, we do glance inadvertently into the sun's disk every once in a while, and we do not go blind.

I was standing on the corner of Seventh Avenue and Fifty-third Street looking up at the sun and an older woman pointedly stated as she passed by: "Don't look at it; you'll go blind." I was about to give her a minilecture on understandable journalistic exaggeration, but I desisted and took pleasure instead. Go back to all those stereotypes about New Yorkers. Legend holds that we never talk to strangers, but she had reached out to me. The crescent of the sun beamed upon this domain of anomie and made us a momentary community.

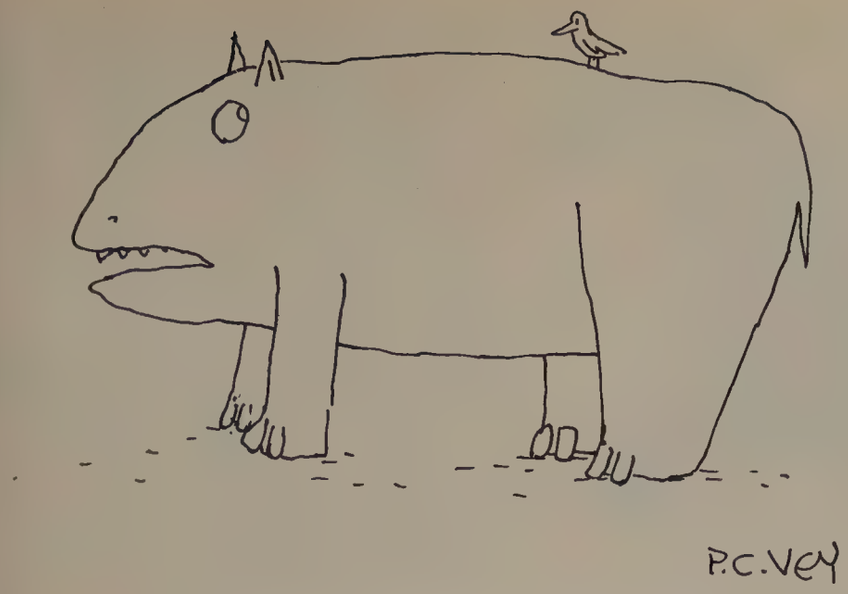
But most people, and quite rightly, did not look directly at the sun, and took official advice for observation by a clever set of devices for filtering or projecting images. And I became grateful for this panoply of strategies during my humanistic "field trip" for science through the streets of New York, for the viewing devices provoked discussion and encouraged sharing, and thus helped to forge the eclipse community.

Some people looked up through filters. A young man had prepared several strips of overdeveloped film, and he passed them around, a double layer for each observer (as the newspapers had advised), to all interested parties. A welder on Fifty-third Street spent his work break sharing his goggles with the gathering crowd.

Others took advantage of a wonderful phenomenon in optics, using the principle that almost any small hole or space will act as a pinhole camera to project the image of the crescent sun. Here New York City even holds an advantage over the country—for an image projects badly upon rumpled ground, but ever so well against a smooth white sidewalk. New York is such a wondrous mixture of colors, classes, dress, and activity (I have seen many cities more beautiful and exotic, but none more diverse). But we so rarely come together, for what can transcend our differences and forge common concern? And what answer to this query could be more elegant or literal than the pervasive sun itself?

On Fifty-eighth Street, a West Indian janitor in his work clothes stood in front of an apartment building, where a ripped awning contained several small holes, each of which projected a beautiful image of the crescent sun upon the sidewalk. The janitor, acting the part of a carnival barker, gathered the passersby under his awning to see the grand sight, gratis of course. At the next building, like the proprietor of the adjacent stall at the same carnival, an Asian man pierced holes in envelopes, sheets of paper, and manila folders, showing people how to project the sun's image upon the ground—again for free and for the sheer pleasure of sharing.

People gathered on every street to show off their newly discovered devices for projecting images. Trees attracted the greatest crowds, for the spaces between leaves act as little cameras, and hundreds of dancing crescent suns appeared on the sidewalk amid the shadows of branches and leaves.



"I think you're becoming too dependent on me."

One woman, elegantly dressed and dangling a cigarette from her lips, held up her hand into the path of sunlight at the eclipse's acme, and a crescent image appeared at the bottom of the space between each pair of adjacent fingers. She squealed with delight and the people around her cheered. A boy then took off his adjustable baseball cap, unsnapped the connecting band, and projected a sun through each tiny hole of the band. And again, people cheered.

I have watched eclipses with relish for all my conscious life. Like all devotees, I have my favorite stories and main events. I remember my best lunar eclipse, seen when I was a teen-ager from the twenty-fifth floor of a friend's apartment, high over Manhattan. The fully covered moon often turns dark, but may also glow with a variety of colors. On this night, the entire disk of the eclipsed moon turned red, a deep dark red that I had never seen in the heavens, or perhaps even on earth. And I understood that two verses from "The Saints" are descriptions of solar and lunar eclipses, not abstract scare stories of eschatology (I played washtub bass in a folk group at the time, and we often performed this song): "When the sun refuse to shine...when the moon turns red with blood; oh Lord, I want to be in that number, when the saints go marching in"—a description, after all, of the Last Judgment, when eclipses will accompany the panoply of awful events. Did not the prophet Joel also speak as an astronomer in citing the same image for the same purpose: "The sun shall be turned into darkness, and the moon into blood, before the great and the terrible day of the Lord come" (Joel 2:31).

And I remember, for how can one blessed with an opportunity to witness this most spectacular of all celestial events

ever forget, the total solar eclipse of early 1970. Our department rented a fishing boat to sail off Nantucket, the only bit of New England real estate privileged with a view of totality. I longed to see the moon's shadow fully cover the sun; I thrilled at a chance to observe the sun's corona. But I had not understood the most awesome phenomenon of all. We live in a natural world of shadings. Even catastrophes have foreshadowings: clouds precede thunderstorms, and tornadoes can be seen in the distance. But when the sun enters total eclipse, the sky turns off as if a celestial janitor threw a switch. For the sun is powerful, and a fraction of one percent of sunlight is daytime, while totality is nighttime—and the transition is a moment, a twinkling of an eye. The sky turned off, and my infant son cried in my arms.

We hear so many dire warnings about the poor quality of science teaching in our schools, so many lamentations over the profound ignorance of most Americans about nearly any phenomenon of the natural world. Perhaps these jeremiads have validity; half of my own students could not explain to me why our planet has seasons. Surely we should be struggling to increase literacy in science, for no issue of education could be more important.

Toot Owl
Derek Pell

But I am convinced that the problem does not arise from lack of interest. Such a false charge is often made amid the litany of correct accusations mentioned in the last paragraph. Interest is immense, but not always expressed as activity traditionally called science or ranked among its pursuits (and our misattribution therefore arises from our inadequate taxonomies of intellectual enterprise). My colleague Phil Morrison is fond of cataloging the large number of common activities requiring a good deal of scientific understanding, but not usually so classified: the astronomical knowledge of people who build and maintain telescopes; the deep botanical experience of members in gardening clubs (a fine example of power concentrated in older women); or even the people who frequent race tracks and bet intelligently on horses (some really do!), for misunderstanding of probability may be the greatest of all general impediments to scientific literacy.

May I now add to this list the aggregate intellectual power (how I wish we could quantify it) of all the dinosaur names accurately memorized (and spelled) by millions of five-year-old kids in America today. And also the accumulated joy and pleasure of millions upon millions of Americans who paused to watch the sun and to wonder on May 10, 1994. New York City was the best place to be on that date; my faith in raw interest is fully affirmed—and raw interest is the substrate and sine qua non of any real reform in education and larger understanding.

We often argue that only misfortune can bring us together. We do help one another during snowstorms; we do open our hearts and our houses to victims of an immediate

disaster in our vicinity; we will search all night in the woods for a lost child we do not know. All these observations properly give us hope about common humanity in a world more often characterized by thoughtlessness, self-serving action, and even downright cruelty. But we also suppose that only disaster can provoke this effect, never pleasure, and certainly not intellectual as opposed to purely visceral delight. But interest and curiosity can also bring us together—and my observations of New Yorkers delighting in nature and spontaneously talking about the sun somehow give me more hope than our joint courage in times of crisis, even though unity in disaster may make me cry in sublime appreciation, while the bonding of eclipses only makes me smile.

And so I end this essay by quoting the greatest of all tributes to the sun. I have often stated my personal theory about popular writing in science. I divide this genre into two modes, which I call Galilean, for intellectual essays about nature's puzzles, and Franciscan, for lyrical pieces about nature's beauty. I honor Galileo for writing his two major works as dialogues (actually trialogues) in Italian, and therefore addressed to all thinking people in his orbit, and not in the formal Latin of churches and universities. And I honor Saint Francis of Assisi for his tributes to nature's loveliness.

I am an unrepentant Galilean. I work in a tradition extending from the master himself to Thomas Henry Huxley in the last century to J. B. S. Haldane and Peter Medawar in our own. I greatly admire Franciscan lyricism, but I don't know how to write in this mode. I began this essay with a quotation from the eponymous hero of my literary bloodline, Galileo himself. But my essay talks about the power of the sun to unify our diverse cultures and concerns, so I must end with a man I have never quoted before in these columns, the eponym of the other style—Saint Francis of Assisi. Saint Francis composed his beautiful *Canticle of Brother Sun* in 1225. He wrote in the Umbrian dialect of his local people, and his poem is often regarded as the first preserved in any modern language:

Brother Sun, who brings the day…
How beautiful he is, how radiant in all his splendor!

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

Chitty Canyon, Arizona

by Robert H. Mohlenbrock

Roughly tracing the route traversed 450 years ago by Francisco Coronado in his search for the fabled Seven Cities of Gold, my student Rod Doolen and I drove south along U. S. Highway 666, a few miles west of the Arizona–New Mexico boundary. We soon came to the brink of the Mogollon Rim (pronounced muggy-OWN), which separates the cool, pine-clad Colorado Plateau to the north from the hot, dry lowlands—and desert—to the south. More than 200 miles long, the Mogollon Rim is the highly irregular edge of the plateau, running from northwestern Arizona southeastward to the vicinity of Strawberry and then more or less eastward across eastern Arizona and western New Mexico, eventually connecting with the Mogollon Mountains. We paused at an observation point where the terrain dropped abruptly nearly 3,000 feet to the valley below. After enjoying the view, we headed to nearby Chitty Canyon, managed by the Apache–Sitgreaves National Forest, to explore the vegetation below the edge of the plateau.

Pipsissewa, a relative of wintergreen, blooms in late summer.
Bob and Clara Calhoun; Bruce Coleman, Inc.

Taking a Forest Service road west from the highway, we arrived close enough to the upper end of Chitty Canyon to park our car and hike in. While a forest dominated by ponderosa pines covers the slightly lower plateau north of the Rim, here we stepped out into a fir-aspen zone, about 9,500 feet above sea level. Closely crowded Douglas firs, white firs, Engelmann spruces, and quaking aspens were enshrouded by low-hanging clouds. The heavy shade of the trees inhibited the growth of understory vegetation, but a number of attractive wildflowers thrived in the moist soil. They included the delicate calypso orchid, the mottle-leaved rattlesnake plantain orchid, wintergreen, pipsissewa (a relative of wintergreen), and spring-flowering coralroot. The last is an orchid that lacks chlorophyll and must obtain its nutrients from the organic matter in the soil.

The dense forest of the fir-aspen zone extended down to about 8,000 feet, continuous except for small openings where the soil was too thin for trees to grow. These openings, all less than five acres in size, were high meadows where, because of overgrazing by domestic livestock, the native vegetation had been replaced by weedy species such as bracken fern and western sneezeweed. (A few miles to the north, pristine Hannagan Meadow presents a high mountain meadow of native grasses and wildflowers.)

As we descended by trail to about 8,000 feet, the forest began to open up, and the Douglas firs, white firs, and Engelmann spruces were replaced by ponderosa pines and smaller trees such as Gambel's oak, gray oak, Rocky Mountain maple, and alligator juniper. The trees were more widely spaced, allowing sunlight to filter through to the forest floor, where the soil was hotter and drier than in the fir-aspen zone. Still, some Douglas firs and quaking aspens were doing well in rocky crevices and other protected areas, even below 8,000 feet.

Conditions were drier still on the steepest south- and west-facing slopes and on the ridgetops, at elevations between 7,000 and 8,000 feet. Gambel's oak and alligator juniper were smaller and more gnarled, and the shrubby, white-fruited snowberry was plentiful. Scattered wildflowers included beargrass, banana yucca, mescal, prickly pear cactus, and wild lotus.

Below 7,000 feet, down to the bottom of Chitty Canyon at 4,500 feet, the vegetation consisted of scattered, round-topped, piñon pines and alligator junipers. Grasses filled in the understory, along with Indian paintbrushes and beardtongues.

Chitty Creek, which long ago carved the canyon, is fed by rainfall, snow melt, and groundwater from several springs. Lining the creek and its tributaries were box elder, Arizona walnut, lance-leaved cottonwood, and thick-leaved alder. Red-osier dogwoods formed occasional thickets, all the more conspicuous because of their scarlet twigs. Wildflowers abounded, including a gorgeous yellow columbine, a tall blue larkspur, bright yellow buttercups, white-flowering violets, and two kinds of false Solomon's seals.

Here and there between 8,000 and 8,200 feet were seeps, places where groundwater oozed to the surface from

A decaying ponderosa pine overlooks the slopes of Chitty Canyon.
Randy A. Prentice

On the plateau near the Mogollon Rim, a New Mexican locust tree grows beneath quaking aspens.
Jack W. Dykinga

springs. These soggy openings, free from woody plants except for an occasional Bebb's willow, were filled with fall panic grass, bog orchid, yellow-eyed grass (a member of the iris family), golden-glow (a black-eyed Susan with a yellow center rather than a black one), and Macoun's buttercup.

Chitty Canyon is only one of hundreds of inviting areas along the Mogollon Rim, which extends into several national forests. (Because the region includes private holdings as well as part of the Apache Indian Reservation, a Forest Service map is essential for guidance.) There are many places to camp, both on top of the Rim and in the lands below. Few roads link the two areas, however. Where we stopped along the highway was one of only six places in more than 200 miles where a paved road goes from the high country to the low. In fact, only a limited number of hiking trails go up and down the face of the Rim; each is difficult, often strewn with loose, crumbly rocks, and treacherously muddy following a thunderstorm.

Robert H. Mohlenbrock, professor emeritus of plant biology at Southern Illinois University, Carbondale, explores the biological and geological highlights of the 156 U.S. national forests.

Chitty Canyon

For visitor information write:
Forest Supervisor
Apache-Sitgreaves National Forest
Federal Building, Box 640
Springerville, Arizona 85938
(602) 333-4301

Joe LeMonnier

Photo by E. Sowers

Carol Bowman and Ernie Sowers,
Save the Children Sponsors

"What I saw in Honduras changed my life."

Carol Bowman

Sponsorship isn't new to Carol Bowman and husband, Ernie Sowers. For eight years they've been sending monthly gifts to Save the Children to help three little girls in Central America.

Letters from the girls and regular progress reports have allowed Carol and Ernie to "watch" their sponsored children grow from thousands of miles away.

But this past year, they decided to visit eight-year-old Miriam in Honduras. "Not until you're there and see how the people struggle do you realize the magnitude of their needs," recalls Ernie. "Homes were shanties, patched with scraps of cardboard. The little water that was easily accessible was not safe to drink.

"I thought the reason so many children were half-clothed was the heat. But it wasn't. In a place where food, water and medicine are scarce, clothes are counted a luxury few can afford."

Ernie and Carol wanted "to scoop Miriam up and take her away from all that misery." But that's not the way Save the Children works. Instead, our programs help provide food, education, medicine — things her parents want to give her but can't.

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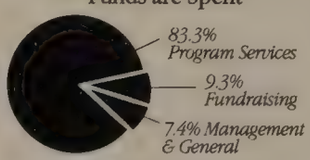

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Terminal Man

It's been real

by Roger L. Welsch

As if one reality weren't more than enough for most of us, computer cybersillies are offering so many alternative realities that there are catalogs for the casual reality browser. A major national magazine recently asked me to review a set of virtual reality computer programs that would have allowed me to wander aimlessly (on my computer screen) around Yellowstone Park, Death Valley, the rilles of the moon, or the plains of Mars. These were not phony ideas of what Yellowstone and Mars might be like; these were the actual landscapes you would find if you ever went to the trouble of going there. For the moon and Mars, as I understand it, the data collected by earth satellites and space robots have been translated into these programs, and rapid reading and display on the part of powerful home computers and compact-information packages allow you the feeling of moving freely even on landscapes no one has ever walked.

So why didn't I do the review? Because I couldn't understand the first paragraph of the instruction book telling me how to install the blasted program into my computer, that's why. But my ignorance is certainly no reason for me not to have opinions about reality, right? I've been exposed to other alternative reality computer programs. Even to alternative realities.

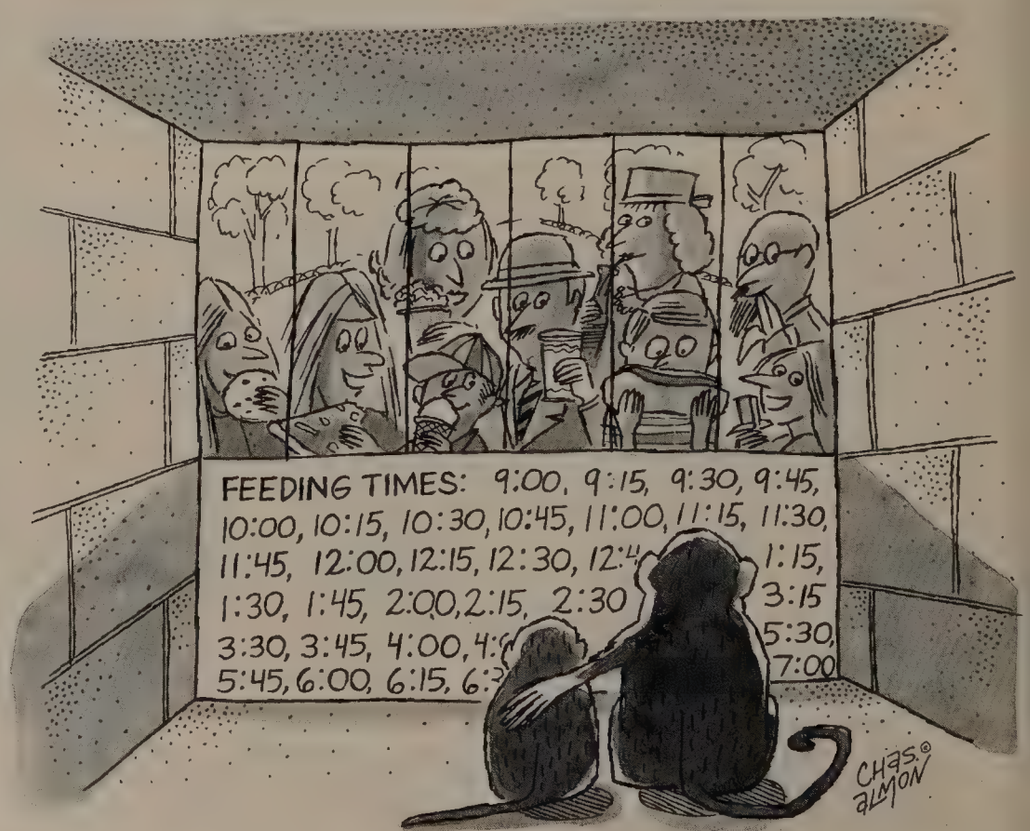
One of my areas of academic interest is "living history" museums. I was, for example, a consultant at the Plimoth Plantation Museum in Plymouth, Massachusetts, where a talented and dedicated team of researchers, artisans, and actors do their best to give visitors the impression they have gone back 370 years in time and are actually within the Pilgrim village of Priscilla Mullens and John Alden.

And how about CityWalk, a Los Angeles alternative reality that opened a little over a year ago? CityWalk is a replica of a street in Los Angeles for people who are in Los Angeles and want the feeling of being *in* Los Angeles without *being* in Los Angeles. For $100 million MCA built a block of Los Angeles without the unpleasant stuff, which is to say, Angelenos. (Don't write me nasty letters; I'm only telling you what they did!) Real earthquakes may occur in CityWalk—I don't know—but I'm betting they simulate earthquakes every day, a little after lunch. The intent of places like Plimoth and CityWalk, whatever their differences, is the same: to distort your sense of reality by giving you an alternative to the reality you already have right in front of you most of the time. When you think about it, that's what writers do, and playwrights, actors, producers, and artists of every other variety.

And it's not as if there is one "real" reality. In fact, there is at least one reality for each human being on earth, maybe more. The world as seen by a traditional Omaha from the tribal reservation in eastern Nebraska is distinctly different from the reality of an academic at the University of Nebraska or a farmer on the central Plains or a corporate executive in New York, in ascending degrees of separation. What each sees as he or she looks out the window in the morning is not what the others see. It is no less valid, no less real, no less important, but it is not the same.

I was once visiting my mother and father's home with my son, Chris, when he was just a tyke, maybe a year old. He had been there many times before. In those days we lived in a woodsy area, and our neighbors on two sides were horses. As a result, Chris's world revolved around his parents (BOR-ing!) and horses (FAS-cinating!). On this occasion I carried Chris into my parents' home and he immediately began a pounding repetition of one of the few words he knew, "Horsie, horsie, horsie, HORSIE, HORSIE, HORSIE!"

But there were no horsies. My folks live in a thoroughly residential area where there is no livestock. None. No horsies.



We tried to tell Chris that. But he was firm. He screamed, he yelled, he insisted.

Finally, in desperation, I picked him up and held him out in front of me, like a small, human Geiger counter. As he pointed and beeped "Horsie, horsie, horsie," I responded to his pointed finger and the volume and frequency of his beeping to find out what was arousing his excitement. I followed his finger out of the living room, through the dining room, and into the kitchen. I wound up with Chris a little above waist level, pointing intently into a corner of Mom's cupboard at a toaster.

"No horsie, Chris," I tried. He insisted. He insisted so intently, in fact, that I finally put him on the floor, still screaming "Horsie," and leaned forward into the dark corner where he pointed. I pulled out the toaster. Chris went berserk: "Horsiehorsiehorsiehorsiehorsiehorsiehorsie." I looked at the toaster. I took off the plastic cover. Chris pointed at the cover.

I found that if I looked at the cover closely, if I squinted and held it just right in the light from the window, I could see that the pattern on the toaster cover was actually an interlocking set of stylized, geometric horses. "My God, the kid is a genius," Mom sobbed.

Well, yes, in keeping with family tradition, he is a genius, but the thing is, at that point his life was horsies. He didn't give diddly about hundred-dollar bills falling from the sky or Madonna at our door asking for help with the flat tires on her limo or Mick Jagger asking his dad to play bass for just a couple of gigs along the West Coast. What Chris cared about, what his reality consisted of, was horsies. And that's what he saw.

Chris had no choice. Most of us don't. We have whatever reality was issued us or whatever reality we have stumbled into, but we don't get to pick and choose.

Well, brace yourself: Computer jigglers are giving us the chance to go somewhere without going anywhere. Bill Orr, erstwhile First Gentleman of Nebraska, once told me that he liked to think of *National Geographic* and *Playboy* magazines as being pretty much akin, each showing us exotic and romantic places we were almost certain never to visit. Well, Bill, that day is over. Now you can visit such places at will: You can climb the sheer face of El Capitan while seated at your own computer or (if you're not in shape) use the *Penthouse* interactive CD-ROM to freeze-frame *Photograph* "while three *Penthouse* Pets cavort."

Zygon's SuperMind *Virtual Sex* experiment may be beyond virtual reality, since it provides no images, just a set of "erotic" brain wave impressions. Zygon promises to "implant erotic 'virtual sex' fantasies onto your brain cells." I found myself confronted with my own experiential limitations, however, when I tried to imagine how the "sounds of crickets," one of the effects promised by Zygon, fit into romance. Every woman I've ever had anything to do with finds crickets and sex mutually exclusive.

After surveying the literature, I was so confused, I felt I needed to talk with a philosopher. So I sat down with Lovely Linda and told her what is going on out there in front of computer terminals. "I can't figure out," I said, "whether people who want to stroll on Mars and play footsie with Doxie Lustina are overwhelmed by the kind of reality I find charming or are so bored by it they need more."

Linda started thumbing through the brochures I had put on the table.

"What are you looking for?" I asked.

"I'm not interested in hiking on Venus or cavorting with Fabio," she said, still looking through my file. "I want to see if they have a program that will give me the feeling of what it's like to walk through a clean house."

Folklorist Roger L. Welsch lives on a tree farm in Dannebrog, Nebraska.

Sirius Matters

by Gail S. Cleere

On or about August 10, shortly before dawn, the snout of the constellation Canis Major (the Great Dog) will poke its way up over our eastern horizon, carrying with it the jewellike star called by the Greeks "the sparkling one." This is Sirius (the Dog Star) making its annual appearance in our summertime sky. Astronomers call the event "the heliacal rising of Sirius." To the ancient Egyptians, Greeks, and Romans, the appearance of Sirius in the morning sky heralded the hot days of summer—the dog days.

The ancient Egyptians looked forward to the summertime appearance of the Dog Star because its arrival preceded the annual flooding of the Nile, upon which Egyptian agriculture depended. About 3000 B.C., the rising of Sirius occurred earlier in the year, near the time of the summer solstice. A few thousand years later, however, Sirius acquired the bad reputation of bringing on "fever in men" and "madness in dogs." Homer described it in the *Iliad,* when from the walls of Troy, King Priam watched Achilles advance:

> Blazing as the star that cometh forth at Harvest-time, shining forth amid the host of stars in the darkness of the night, the star whose name men call Orion's Dog. Brightest of all is he, yet for an evil sign is he set, and bringeth much fever upon hapless men.

The Romans sacrificed young dogs at Sirius's appearance, and Dante spoke of the "scourge of days canicular." Even in our own times, researchers at the National Institute of Mental Health (NIMH) study the links between the hot days of summer and the manic behavior of those suffering from manic-depressive illness. In his book on seasonal affective disorders, *Winter Blues,* NIMH psychiatrist Norman Rosenthal details the history of Anne Grenville in the late 1600s, whose seasonal mania became so troublesome in the summer that one of her physicians suggested special treatments "at the approach of the dog days." I wonder what they were.

Today we recognize Sirius, at –1.46 magnitude, as the brightest of the fixed stars visible to the naked eye, and at 8½ light-years distance, it is the third closest "naked-eye" star to us. We moderns may no longer be aware of Sirius's ancient relationship with summertime heat, but we do recognize it as that brilliant wintertime object just below the right foot of the great constellation Orion the Hunter. (Sirius is ten times brighter than any of the neighboring stars in that constellation.) At the Christmas season, Sirius rises over the horizon at about 7:00 P.M.

But the brilliant light of Sirius is not from Sirius alone. In 1862 a mild-mannered telescope maker in Massachusetts looked through the new 18½-inch lens he had just made and discovered that Sirius was actually two stars—a discovery that, like so many in astronomy, had actually been predicted. What Alvan Clark had found was Sirius's white dwarf star companion, now called Sirius B, or the Pup. Clark had been fantastically lucky. The atmospheric "seeing" conditions had to have been superb, for many others had searched for this suspected companion and had not found it. Today it can be seen with much smaller telescopes, but only if conditions are right and if one knows exactly where to look.

We now know that Sirius B represents what will happen to more than 95 percent of all stars, including our own sun; after it burns all its available fuel, it will swell to a red giant and then collapse in on itself into a superdense, superheated ball. Shining at 8.65 magnitude, Sirius B is about the size of the earth. A cubic inch of Sirius B weighs as much as a dump truck. This washed-up star's crushing gravity is awesome, and its stupendous temperatures are thousands of degrees Kelvin hotter than the sun. The Pup is ending its days as our own star will—but in the sun's case there will be a sad collection of airless worlds all around it, and in at least one case, a world whose oceans have boiled away.

Nonetheless, it is the main star of this duo, Sirius A, that provides us with the brilliance we appreciate. When seen through the thick layer of atmosphere along the horizon, Sirius's blue-white fire can appear to flicker with the colors of the rainbow and may explain the ancient descriptions of the star by Aratus, Cicero, Horace, Seneca, and Ptolemy as "yellow," "ruddy," "reddish," "blazing as fire," and "shining like copper."

As the days go by, try to find Sirius in the hours before dawn, rising just south of due east along the compass. As the year progresses, Sirius rises earlier by four minutes each day, becoming easier and easier to find in the night sky.

The Planets in August

Mercury will likely become lost in solar glare after August 2.

Venus remains in the southwestern sky this month, but proceeds to get lower in altitude because the angle of the planet's path across the sky is quite low relative to our horizon. Look for bright Venus about fifteen degrees above the west–southwest horizon at sundown. On the evening of the 10th, the waxing crescent moon sails three degrees below Venus. On the 31st, look for the star Spica just above and to the left of the planet. The *Magellan* spacecraft—currently in orbit around Venus and scheduled to have been turned off by NASA in April—has received additional funding to keep it up and running. It will continue its gravity-mapping mission through the end of this fiscal year.

Mars rises well after midnight in August, moving from Taurus into Gemini. On the morning of August 3, look for Mars shining like a yellowish orange star roughly six moon widths above and slightly to the left of Orion.

The 1996 Russian mission to put rovers and balloons on Mars has been pushed back to 1998. This is because the monies for the project have been diverted to the Mars '94 mission, now rescheduled for 1996. NASA has also proposed an exploration program for Mars, called the Mars Surveyor, to begin in 1996. At that time, the space agency proposes to begin launching both orbiters and landers every two years to the planet.

Jupiter is a wonderful summertime planet this year and in August moves eastward into Libra, heading toward the "claw" stars of the Scorpion. (The giant gas planet's collision with Comet Shoemaker-Levy 9 in July is not expected to have any lasting effects.) It can be seen well up in the southwest at sundown. On the 15th, look for Venus, Spica, Jupiter, Antares, and the first-quarter moon spread like jewels along the southwestern sky.

Saturn rises shortly after sunset and is visible throughout the night in Aquarius—a rather dim constellation well east of the bright stars of Scorpius and Sagittarius—and Saturn is by far the brightest "star" in the area. On the evening of August 21, you'll find Saturn shining roughly eleven moon widths below and to the right of the nearly full moon. Look for the ringed planet below the full moon on the 22d.

Uranus and **Neptune** steadfastly cling to the eastern region of the constellation Sagittarius, edging ever so slowly toward the constellation Capricornus. Look with binoculars for two bluish green disks well up in the southeast at sundown.

Pluto is the wallflower of the solar system, difficult to spot, elusive, and all but lost among even the faintest stars in our August night sky. He watches the goings-on of Jupiter, Saturn, Uranus, and Neptune, from his perch in the sky above the stars of Scorpius and Libra.

The **Moon** is new at 4:45 A.M., EDT, on August 7; reaches first quarter at 1:57 A.M., EDT, on August 14; is full on the 21st at 2:47 A.M., EDT; and reaches last quarter on the 29th at 2:41 A.M., EDT. The full moon of August is traditionally called the grain moon, the woodcutter's moon, or the dog day's moon. The Algonquin Indians called it the sturgeon moon. The Sioux called it "the moon when the cherries turn black."

The Perseid meteor shower, one of the best known of the annually occurring meteor showers, reaches its peak on the night of August 12–13. In dark skies, some fifty to sixty meteors an hour can generally be seen at the Perseid shower's peak, and these are typically yellow and white, with some that can be very bright green, orange, and red, leaving spectacular trails up to two degrees wide. The Perseids are remnants of Comet Swift-Tuttle, first seen in 1862 by astronomers Lewis Swift and Horace Tuttle, and rediscovered in September 1992 by Japanese amateur Tsuruhiko Kiuchi. Last year's predicted spectacular display of the Perseids never materialized, and some astronomers believe 1994 might be the year the earth passes through the particularly dense knot of cometary matter that is theorized to follow the comet itself. With the moon setting shortly after 11:00 P.M., EDT, the dark hours following moonset are the time to watch for these meteors.

Gail S. Cleere lives in Washington, D.C., and writes on popular astronomy.

Pacific Requiem

A half century after the defeat of the Japanese at Guam, Micronesia still bears the scars of war

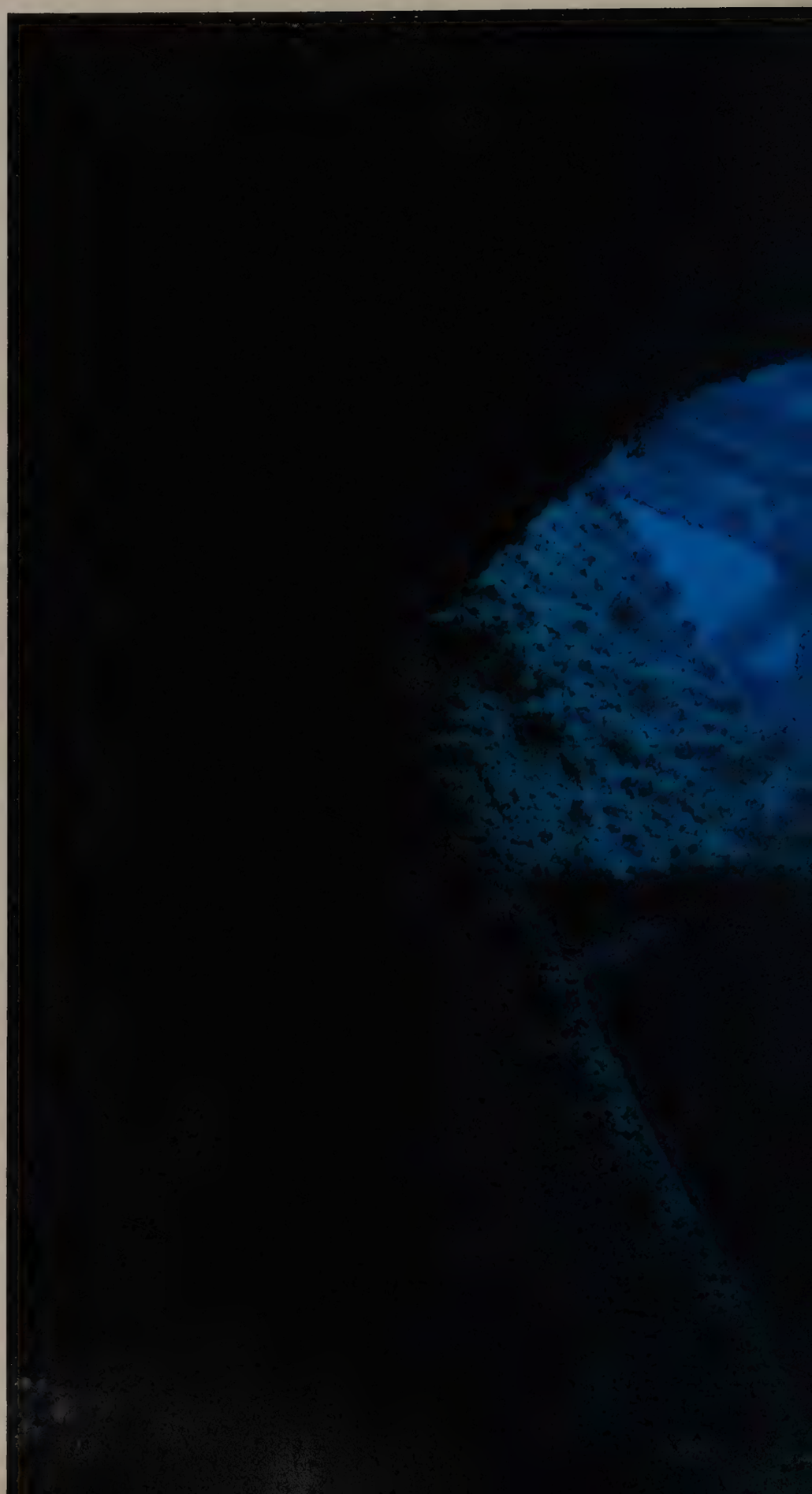
by Daniel J. Lenihan

The *Cormoran* lies in its grave, steel coming to terms with seawater. The ocean always prevails in these cases, but the process is long and intriguing. Swimming slowly aft along the port side of the ship, which rests on its starboard side, my companions and I leave an ever widening trail of bubbles from our regulator mouthpieces. I lead a team of National Park Service underwater archeologists that first came to this site off the Pacific island of Guam several years ago. We are curious to see how time and increased sport diving have affected the site.

A commerce raider—a warship designed to prey on enemy merchant shipping—the SMS *Cormoran* was built in Russia but flew a German flag. It was scuttled in Apra Harbor under orders from its captain on April 6, 1917, the day the United States entered the Great War. Through this act of defiance, the interned vessel was kept from falling into enemy hands and its crew became some of America's first prisoners of war.

Guam has an active community of sport divers, augmented by American military personnel and tourists. Barely visible above us, the bobbing forms of a large group of Japanese divers begin their descent from a tour boat. With pristine reefs to dive on nearby, one might wonder what attracts so many Japanese sport divers to a World War I relic during their weekend getaway from Tokyo. Most likely their attention is focused on the object that is casting a shadow over the *Cormoran*'s stern—the looming hulk of a World War II Japanese transport. Lying keel to keel with the scuttled German ship is the *Tokai Maru,* a World War II casualty of American torpedoes.

One of America's most far-removed possessions, Guam lay deep within the zone that the architects of imperial Japan termed the Greater East Asia Co-Prosperity Sphere—a huge, vaguely defined region that would achieve economic independence from the West through Japan's military protection and administrative leadership. The Co-Prosperity Sphere included most of East and Southeast Asia,



Light filters through the starboard railing of an upper deck of the Tokai Maru, *a Japanese transport. Sunk by American torpedoes during World War II, the ship lies on its port side at the bottom of Guam's Apra Harbor.*

Larry Murphy; National Park Service

encompassing territories the Japanese already controlled and others they wanted to control. Among the key components were Korea, a reconstituted China, the Philippines, and Japan's "Micronesian mandate"—areas that Japan had seized from Germany during World War I. For a brief period from 1940 to 1942, Japan's sights were also set on the Hawaiian Islands.

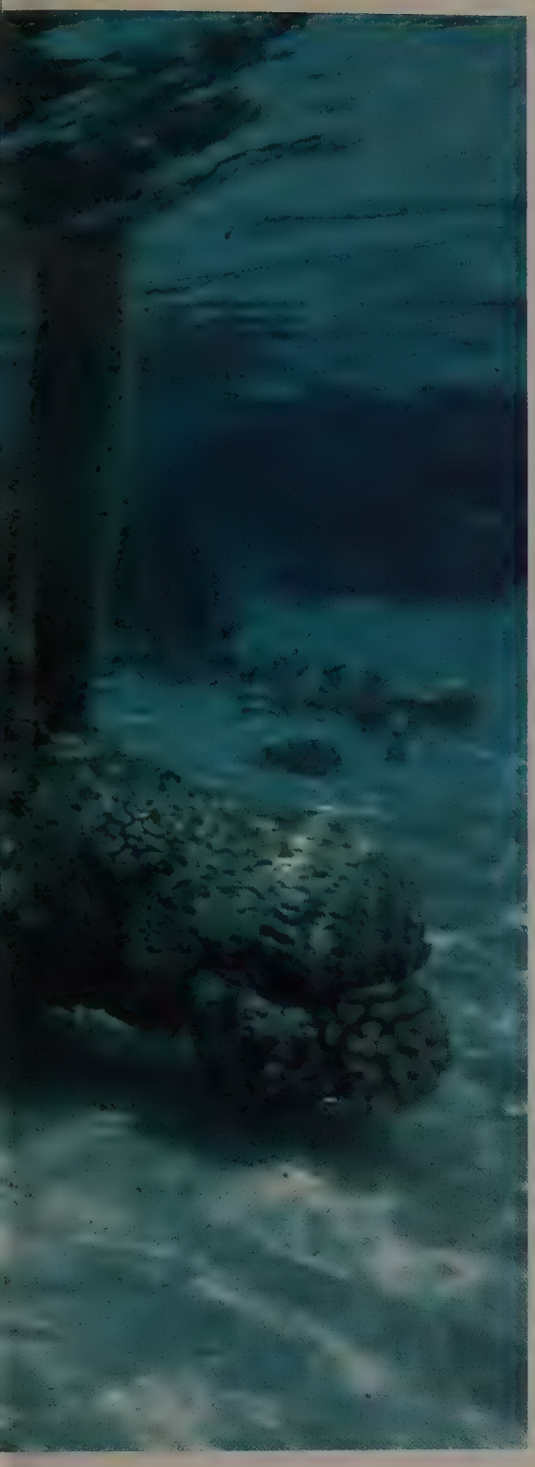
Guam, west of the International Date Line, was plunged into World War II on December 8, 1941. Within hours of the attack on Pearl Harbor, American forces on Guam withstood a Japanese air raid; two days later they surrendered the island to invading ground troops. In July and August of 1944, the reinvasion of Guam by U. S. troops, following on the heels of the fall of Saipan, made it clear the sun would soon set on the Japanese empire and any vision of a Japan-controlled Pacific.

Over the course of a half-dozen field trips to Micronesia during the past fourteen years, I have been impressed with the detritus of war. Nowhere is it more evident than in these islands, especially underwater. Given that a rage to reorder and rebuild typically follows periods of human conflict, the past is less likely to be trampled if it is beneath the sea.

As we glide effortlessly between the *Cormoran* and the *Tokai Maru* on the bottom of Apra Harbor, images of two wars slip by in metallic shades of blue. The color blue is the only concession allowed the sun one hundred feet below the water's surface, as the ocean asserts its dominance over the warmer colors of the spectrum. Not far from here is the darkest blue of all—the Mariana Trench.

The most dramatic change we note during our swim is that the stacks of the German raider have fallen into the mud. The Japanese divers, using the bicycling motion typical of inexperienced scuba enthusiasts, stir clouds of silt as they pedal to a perch on the deck of the *Tokai*. They glance down curiously at us as we make our way to the point where the *Cormoran*'s propeller (now removed) punched a hole in the side of the Japanese vessel when the latter settled on the harbor bottom.

We surface from our examination of the two ships and watch the diving "head boat" gather up its covey of flipper-clad tourists. An easy few hours by airplane



John Brooks; National Park Service

One of the engines of a B-24 "liberator" bomber, left, lies off Majuro, an atoll, in the Marshall Islands. Surviving crew members were reportedly captured and executed by the Japanese. Below: A Japanese plane downed by U. S. Navy gunfire greeted Marines streaming ashore at Agat, on Guam, on July 28, 1944.

National Archive; Courtesy of the War in the Pacific National Historic Park, Guam

from Tokyo, Micronesia is to the Japanese what the Caribbean is to many Americans, the difference being that those who are vacationing in the Pacific islands are also gathering on the battlefields of their fathers. Kwajalein, Truk, Palau, Saipan, Guam, Tinian, the Philippines—in 1944 all were part of the string of costly victories for America, and a distant wake-up call for Japan.

The disaster at Pearl Harbor, followed by six months of additional American defeats and setbacks, was dramatically reversed at the battle of Midway and the Aleutians in June of 1942 (*see* "The *Arizona* Revisited," *Natural History,* November 1991, and "Aleutian Affair," *Natural History,* June 1992). The Allied offensive steadily picked up steam through 1943, and the Japanese found themselves fighting desperately to retain control of key Pacific islands and forestall the impending invasion of Japan. By 1944 the war-energized industrial capabilities of the United States had generated an awesome array of high-speed aircraft carriers to carry fierce aerial attacks to Japan's doorstep. Attacks on Truk and Palau (present-day Chuuk and Belau) and the invasion of Guam were setting the stage for anticipated incursions into Japan in 1945.

While thousands of American veterans of the fighting in Europe make their pilgrimage this year to France, especially the beaches of Normandy, their countrymen who fought in the Pacific will reconnect with memories of 1944 in a very different part of the globe. Today, the tropical foliage of these Western Pacific islands, with its peaceful chirping of birds and scurrying of lizards, belies the carnage and horror of the scenes that played themselves out here fifty years ago. For visitors of my baby-boom generation, the awareness that the war was fought in color and not Movietone News black-and-white is often the first revelation.

On Peleliu, an island in the Belauan (Palauan) archipelago, we interspersed our marine surveys with walks through the jungle. Our native colleagues guided us around abandoned tanks, gun emplacements overgrown with hardy tropical vegetation, and caves that had been sealed by the advancing Allies. The complex caves and bunkers built into the hillsides by the Japanese could withstand heavy artillery barrages but became self-made tombs once the enemy had landed and could bring heavy earthmoving equipment to bear. Many caves were simply sealed, their defenders left to suffocate; in other cases flame throwers effectively used up the available oxygen, or fifty-five-gallon drums of gasoline were emptied into the caves followed by a lighted match.

Islands not critical to the Allies' sweep through the Pacific were simply bypassed. Their contingent of imperial soldiers became increasingly isolated as supply lines dwindled, and they prepared for invasions that never came. Pohnpei (Ponape) and Kosrae, in the Caroline Islands, received the attention of the Allies in the form of air raids and naval bombardments, but were not occupied until the end of the war.

Most of the Northern Marianas and the

Assisting surveyors from the National Park Service, three Bikinian divers map the deck of the aircraft carrier Saratoga, left. The ship had survived World War II but was sunk at Bikini during Operation Crossroads, a postwar experiment designed to test the effects of nuclear weapons on naval forces. The small tower erected on the deck held instruments to measure the pressure waves from the blasts.

Caroline Islands, which had passed through the administrative hands of Spain and Germany, were taken over by Japan at the outset of World War I. With the buildup for, and commencement of, World War II, the comparatively benign civilian Japanese government was replaced by a military administration that summarily evicted inhabitants of entire villages.

Two years ago my family and I were witnesses to a Kosraean feast day that commemorated the fiftieth anniversary of the June 6, 1942, displacement of the residents of Malem, a village on the southern coast. In typical Micronesian fashion, the feast day "celebrating" this traumatic event was a joyous occasion of reenactments, parades, floats, and games. My own children were caught up in a sea of brightly dressed adult revelers, who were running races around a schoolyard, throwing candy and money to youngsters, and generally having a marvelous time. I would hate to miss the party the Kosraeans will throw on September 8, 1995, to commemorate the official liberation of the island from the Japanese.

In the tiny harbor of Leluh, on Kosrae, my team worked with a contingent of Micronesian divers to document warships and planes spread beneath the surface. We soon had a string latticework "road map" to follow in the murky water between the World War II relics. Reminding us of the depth of history that can be preserved on harbor bottoms were the nearby remains of a mid-nineteenth-century wooden whaling vessel, its try-pots for blubber still in place. Large lionfish patrolled the debris, their poisonous spines capable of delivering a serious wound to any diver that brushed against them.

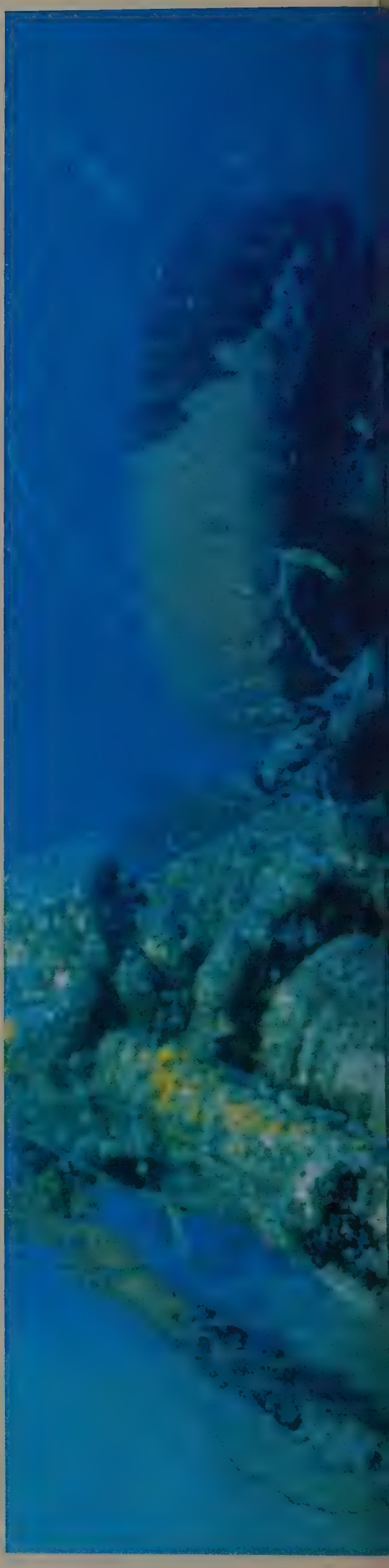
The native islanders carry on with remarkable resilience considering the amount of firepower the industrialized world concentrated on their islands and atolls. In many cases, they have recycled the residues of warfare into their livelihoods. In Truk, a fleet of Japanese transport ships took the brunt of Operation Hailstone at a place that is popularly known as Truk Lagoon. During several days of intense bombing raids in February 1944, carrier-based American bombers and fighters sank more than thirty Japanese vessels. Truk Lagoon has since become a world-renowned destination for diving enthusiasts.

Besides recycling ships into tourist attractions, some Chuukese have been recycling the ordnance on the ships into fishing aids. Members of my dive team recently documented the extent of damage to the ships, corals, and fish that results from the practice of "dynamite" fishing in the lagoon. In the hold of one ship, we found antitank mines, with lifting bags in place, abandoned by salvagers. The fabric of history will fare no better than the fragile marine life if these activities continue in the lagoon. Pilfering divers and anchors dragging from dive boats have added to the destruction, but the ships are still marvelous places to visit.

Throughout Micronesia there are also purposeful deposits of World War II remains, places where thousands of war machines were cast to the waves rather than brought back to flood a peacetime economy. Refuse heaps are always grist for the archeological mill; in land-poor Micronesia, some of the most instructive lie underwater. I followed a trail of war materiel two hundred feet down an underwater ravine in Guam. Trucks, tracked vehicles, guns, ordnance, twisted metal—the items became less distinguishable as the pressure of additional fathoms of water increasingly clouded my brain with nitrogen narcosis. The debris fanned out into the depths, with no end in sight. I had a similar experience in Majuro, in the Marshall Islands, where seemingly sound vehicles were arrayed across the lagoon bottom like Matchbox toys in a bathtub. Ambulances, tow trucks, tankers—a regular bonanza of vintage vehicles going through various stages of a sea change.

The sheer magnitude of goods that industrialized nations could produce to wage war must have left a profound impression on the native islanders of Micronesia. Their neighbors to the south, the Melanesians, have earned a place in anthropology textbooks for their "cargo cults," which arose even before World War I as a response to colonial rule. The subjugated indigenous peoples saw a connection between the power and wealth of the dominant cultures. Messianic leaders heralded the "cargo" ship that would come some day, bearing the riches that would enable the islanders to throw off the yoke of foreign rule.

John Brooks; National Park Service



On July 23, 1944, troops of the 77th Division of the U. S. Army moved inland from Agat, on Guam, below. Discarded after the end of hostilities, one of dozens of war vehicles, right, lies in an underwater grave near Majuro.

Signal Corps; Courtesy of the War in the Pacific National Historic Park, Guam

Ever since the sixteenth century, when Manila galleons carried goods from East Asia to Acapulco, there have been foreign ships in Micronesian waters. The great powers of Europe and Asia have been attracted to the region not only by its strategic location but also by its serenity and remoteness. To American veterans returning to Micronesia, the islands represent a pivotal event of their lives, participation in World War II. They remember fallen comrades, youthful aspirations, a time when they were seemingly immortal and the world was a simpler place. Ironically, many of the hotels where American veterans will be staying during their commemorative visit will belong to Japanese chains. Of late, the Japanese have returned to Micronesia pursuing a commercial, more peaceful vision of a Co-Prosperity Sphere. Developers, hoteliers, and dive guides are succeeding economically where their forebears failed militarily.

For the most part, the Micronesian people welcome the returning veterans from both sides. They also embrace their own past, which includes a war that totally absorbed the lives of their entire families, not just their fighting men. And the smoke had hardly cleared before Micronesia was turned into a testing ground: mushroom clouds became a regular feature on the horizon in the Marshall Islands for a dozen years.

At Bikini, major warships from World War II, including the aircraft carrier *Saratoga* and the Japanese battleship *Nagato,* lie amid cruisers, destroyers, and auxiliaries in the most unusual of the Pacific underwater museums. These ships survived 1944 and 1945; their exploits were breathlessly followed on their home fronts through victory and defeat, and their names were household words. Yet they were considered excess property in 1946 and were offered up in a grand nuclear sacrifice, known by the code name Operation Crossroads.

The stated purpose of Operation Crossroads was to determine how naval forces would fare in a nuclear attack. Some 42,000 men (and 36 women) prepared the test fleet, conducted two blasts (code named Able and Baker), and documented the results in 1.5 million feet of movie film, 50,000 stills, and various measure-

Empty shells lie on the breech of a deck gun of the Fujikawa Maru, *a Japanese transport that was sunk in Truk Lagoon, in the island now known as Chuuk. The shells were probably left there by salvagers who extracted the explosives for use in fishing.*
Larry Murphy; National Park Service

ments. Rivalries between different branches of the armed forces—each competing for prominence in the nuclear age—and a desire to impress the Soviet Union were also factors in the operation.

The most surprising result of the tests was not that some ships sank and some didn't but that radioactive contamination was a much more complex and insidious problem than had been anticipated. Many ships only moderately damaged from the blasts at Bikini had to be sunk elsewhere because attempts to decontaminate them failed. As part of plans to resettle Bikini, I have recommended that the sunken ships there be made into a marine park, a place to dive into history and experience the remains of global conflict, of wars hot and cold (the ships have now "cooled" to safe levels).

From my home in Santa Fe, New Mexico, I can see the lights of White Rock, a bedroom community for Los Alamos. This is where the bombs destined for Bikini were born. A coffee cup that sits on my desk is decorated with the stars and stripes of the Bikinian flag. Inspired by the American flag, it has a few noteworthy differences. The three stars on the right symbolize the islets vaporized in 1954 by a thermonuclear blast (code named Bravo), and across the bottom is written: *Men otemjej rejilo bein anij* (Everything is in God's hands). These were the words spoken by "King" Juda, leader of the Bikinian people, when an American naval officer explained that the islanders had to be moved from their home to a different island so the United States could conduct tests to learn how to use nuclear power "for the good of mankind and to end all world wars."

Will that hope be realized? When the veterans have returned from their commemorative visits to Micronesia, when today has become history and a new team of young archeologists visits the site of the *Cormoran* and *Tokai* in Guam's Apra Harbor, what will they find? Will there be a third ship? As they say in the Marshalls, *Men otemjej rejilo bein anij.* □

Swimming Heads

An underwater encounter with the giant ocean sunfish

by Tierney Thys • Photographs by Mike Johnson

Twenty miles off the southern California coast, our research vessel was approaching a drifting kelp mat when a giant ocean sunfish, or mola, breached beside our boat and quickly submerged again. Within a few minutes, two others rose and floated on their sides. We sidled our boat nearer to the kelp, put on our scuba gear, and slipped into the water for a closer look. About ten feet underwater we saw an overwhelming assemblage of huge molas lined up before us, as if awaiting inspection. As we swam closer, we counted sixteen, varying in color and pattern from evenly dark gray or tan to blotchy and mottled, all with white bellies. They seemed unconcerned as we swam freely among them. Juvenile half-moon fish flitted about the molas, picking parasites from their bodies.

Lacking a true tail, the mola appears to be all head, earning it the German sobriquet of *Schwimmenderkopf,* or "swimming head." Its Latin name, *Mola,* coined by the great Swedish naturalist Linnaeus, means millstone. The creature's common English name of sunfish refers to its habit of resting on its side at the surface. Some biologists believe that such basking—a trait shared with swordfish and leatherback sea turtles—may be a method of warming the body to speed up digestive ability. Small fishes and seabirds feed on the copepod parasites clinging to the bodies of basking sunfish.

Found in all tropical and temperate zones, molas eat small fishes, squid, crustaceans, jellyfish, gelatinous plankton, and algae, but their favorite food is the moon jelly. Ocean sunfish can pursue prey in deep waters. In 1987 one was filmed from a submersible in the Bahamas at a depth of 1,800 feet.

A dozen juvenile half-moon fish, above, feast on a mola's body parasites. The mola's fibrous skin is tough, light, and several inches thick. Facing page: Attracted by a floating kelp mat, with its resident population of small invertebrates, a mola swims just below the surface of the Pacific Ocean near San Diego.

Fused teeth give the sunfish a beaklike mouth, part of a specialized anatomy that sets it apart from most bony fish.

Molas, huge relatives of puffers, are the heaviest of all bony fishes and may weigh as much as 5,000 pounds. E. W. Gudger, an American Museum of Natural History ichthyologist who studied them in the 1930s, proclaimed giant sunfish the "growth champion among animals." Beginning as larvae one-tenth of an inch long, they grow to an adult size of more than ten feet—and increase their original weight sixty million times. Gudger calculated that "the larval sunfish is to its mother as a 150-pound rowboat is to sixty *Queen Mary*s (the *Queen Mary* weighed 80,773 tons).

Despite their size and shape, molas swim gracefully through the water by synchronously flapping their long dorsal and anal fins on one side and then the other. The rear end, or clavus, is hardly a tail and is nearly useless in propelling the fish, but works as a serviceable rudder.

Molas have an extraordinarily tough skin made of densely packed collagen fibers up to six inches thick. In the last century, fishermen's children would bind chunks of sunfish skin with twine to form bouncy balls. The sunfish's skin supports thousands of parasites belonging to forty different species. Even some of its parasites have parasites.

Humans, killer whales, and sea lions also prey upon these gentle, vulnerable giants. In late summer, when large numbers of young, three-foot-long molas follow warm, food-laden currents into Monterey Bay, California sea lions often attack them. The sea lions tear off a mola's dorsal and anal fins and slam the helpless fish against the water's surface. If they fail to rip through its tough skin, the sea lions may toss the crippled mola about like a giant frisbee and finally abandon it to voracious seagulls. □

Although the mola may weigh as much as two and a half tons, it is gentle and approachable. While most female fish carry between twenty and fifty million eggs, a four-foot female mola was found to contain about 300 million—a possible world's record.

To found a new colony, a queen ant of the slave-making genus Polyergus *(right) must enter a* Formica *nest and launch a fatal attack upon the* Formica *queen (left). After repeated biting and licking, the victor acquires the victim's pheromones and, with them, the services of the dead queen's workers.*
Raymond A. Mendez

The Ant Who Would Be Queen

To enslave a foreign colony, a parasitic queen must first murder her royal counterpart

by Howard Topoff

Recently, I found my daughter Andréa studying for an ecology test—in the fourth grade. Surprised, I took the opportunity to ask her if she could name a parasite. "A tapeworm," she said. "You know, that thing that lives in your stomach. Yuck!" Her reaction was familiar; to most people the mere thought of a parasite is unsettling. But people are usually considering only the familiar parasites of humans: various worms, lice, ticks, and other creatures that attach themselves to the skin or internal organs and feed on blood or other body fluids, sapping their host of energy. A more remarkable type of parasitic relationship exists, however. Known as social parasitism, it involves one species relying on another to raise its young. Among vertebrates, the best-known social parasites are such birds as cuckoos and cowbirds; the female lays an egg in a nest belonging to another species and leaves it for the host to rear.

The dulotic, or slave-making, species of ants, however, are the supreme social parasites. Consider, for example, the unusual behavior of ants belonging to the genus *Polyergus,* which I have been studying for many years in the Chiricahua Mountains of southeastern Arizona (*see* "Invasion of the Booty Snatchers," *Natural History,* October 1984). All species of this ant have lost the ability to care for themselves. The workers do not forage for food, feed their brood or queen, or even clean their own nest. To compensate for these deficits, *Polyergus* has become specialized at obtaining workers from the related genus *Formica* to do these chores.

In a slave raid, several thousand *Polyergus* workers will travel up to 500 feet in search of a *Formica* nest, penetrate it, drive off the queen and her workers, capture the pupal brood, and transport it back to their nest. The captured brood is then reared by the resident *Formica* workers until the developing pupae emerge to add to the slave population, which maintains the mixed-species nest. The *Formica* workers forage for nectar and dead arthropods, and regurgitate food to colony members of both species. They also remove

wastes and excavate new chambers as the population increases.

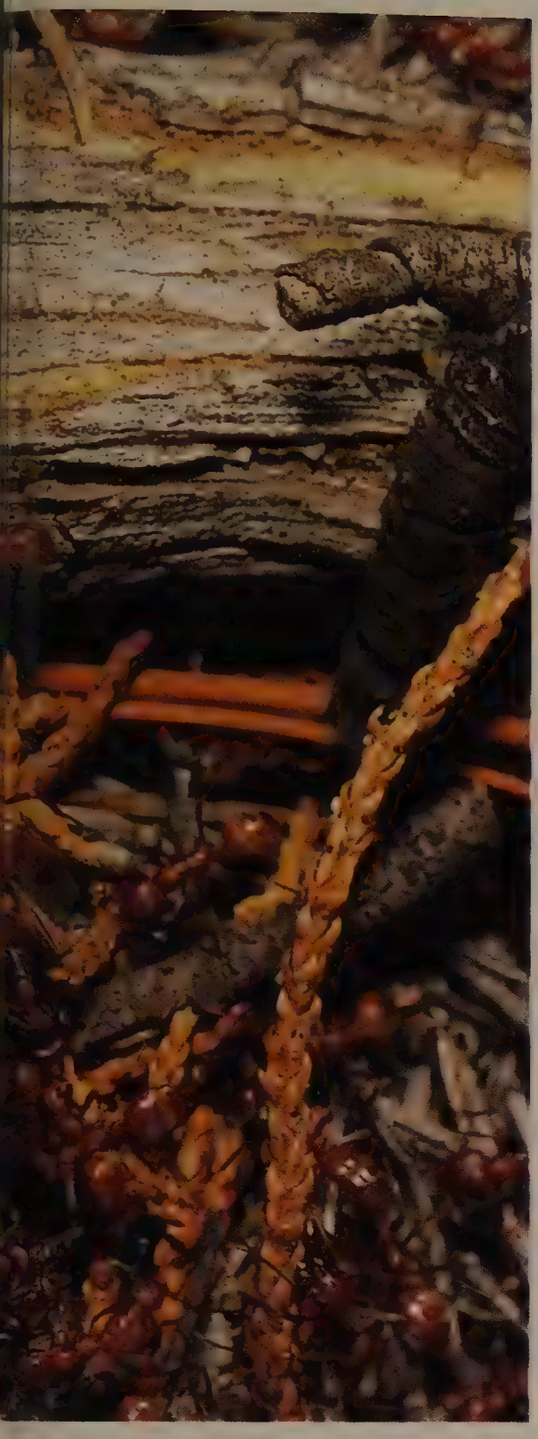
The true extent of the *Polyergus* ants' dependence on their slaves becomes apparent when the worker population grows too large for the existing nest. Scouts of *Formica* locate a new nesting site, return to the mixed-species colony, and recruit additional *Formica* nest mates. During a period that may last seven days, the *Formica* slaves carry to the new nest all the *Polyergus* eggs, larvae, and pupae, every *Polyergus* adult, and even the *Polyergus* queen.

Of the approximately 8,000 species of ants in the world, all 5 species of *Polyergus* and some 200 species in other genera have evolved some degree of parasitic relationship with other ants. At one end of the behavioral continuum are temporary parasites, species capable of caring for themselves, but relying on a host species during the early stages of colony founding. The newly mated queen of the species *Lasius umbratus*, for example, enters a nest of its host, *L. niger,* kills the resident queen, and deposits her own eggs in the invaded nest. The host workers rear her offspring, which as adults scavenge for their own food. Because the host queen is no longer present, the worker force of *L. niger* gradually diminishes through attrition, and the colony becomes a single-species society of *L. umbratus*.

At the other end of the spectrum, the inquiline ants spend their entire life cycle in the nest of the host. In *Teleutomyrmex schneideri,* for example, the entire worker caste has been eliminated and so have the slave raids. The queen of *Teleutomyrmex* is about one-third the size of her host queen, *Tetramorium caespitum,* and capitalizes on her own diminutive size by riding on the host's back. The males and new queens produced by the parasitic female copulate inside the host nest. The newly mated queens then locate other colonies of *Tetramorium* to parasitize, and the cycle of parasitism is repeated. *Teleutomyrmex schneideri* has achieved the highest possible degree of social parasitism, and in so doing it has become utterly dependent on its host. *Polyergus* represents an intermediate stage of parasitic evolution, because it too depends on its host for food and nest maintenance. Unlike *Teleutomyrmex,* however, it still retains a large worker population that must conduct frequent slave raids on other ant species.

But how do such parasitic relationships originate? A cardinal rule in evolutionary biology is that parasitic organisms, be they bacteria, tapeworms, fleas, or slave-making ants, must have evolved from free-living ancestors. For dulotic ants such as *Polyergus,* at least two behavioral adaptations were also essential for social parasitism to evolve. The first is a proficiency for capturing another species' brood in a group raid. This behavior undoubtedly predates parasitism, because many free-living ants conduct predatory raids on other species, as well as territorial raids on neighboring colonies of the same species.

The second adaptation is the ability of queens to found new colonies. In free-living species, winged males and queens fly from their natal nests in search of mates. After this mating flight, a fertile female pulls off her wings, excavates a chamber, lays a few eggs, and later nourishes her larvae with stored nutrients. When the first brood matures into adult workers, they feed the queen and the larvae of her subsequent broods. But this sequence simply will not work for a parasitic ant such as *Polyergus* because the queen can't rear her own larvae. Her only recourse is a seemingly impossible task: to invade a *Formica* colony, kill the host queen, appropriate the brood, and somehow get the workers to accept her as their queen. If she is successful,



During a Polyergus *raid on a* Formica *nest, left, two workers (center, beneath log) carry off a white* Formica *pupa. Below: A* Formica *queen is approached by a worker (right) of her own species after they have been routed from their nest in a slave raid.*
Both photographs by Howard Topoff

resident *Formica* workers will feed her, and within a few days she will start laying eggs. After the eggs hatch, the host workers will rear her brood until her own worker population is large enough to supplement the slave force by staging raids on other *Formica* colonies.

My recent studies of *Polyergus* have focused on the mechanisms by which newly mated queens are able to kill queens of *Formica* and become accepted by the foreign workers. Together with Ellen Zimmerli, one of my graduate students, I returned to the American Museum's Southwestern Research Station, in the Chiricahua Mountains of southeastern Arizona, where I had conducted my original studies. At an elevation of 5,400 feet, the ants inhabit a woodland dominated by Arizona oak, alligator juniper, and Chiricahua pine trees. Here, *Polyergus breviceps* is the only slave-making ant, and *Formica gnava* is its only host.

Like most ants, both species nest underground, so that the interactions between host and parasite queens cannot be observed in the field. Fortunately, colonies of *Formica* are easy to collect, and they thrive in the laboratory, where they can be observed under a low-power microscope. A day prior to each test, we put fifteen *Formica* workers, fifteen pupae, and one queen in a plastic petri dish "nest," which was placed in a larger tray to prevent ants from escaping. At the beginning of each test, these workers stood motionless, surrounding the pupal brood.

When we introduced a newly mated *Polyergus* queen into the tray that surrounded the nest, she would scramble around randomly until she located the small nest entrance. Once inside, however, her actions became deliberate. She bolted straight for the *Formica* queen. Armed with powerful mandibles, she delivered lethal bites to several *Formica* workers who attempted to attack her and repelled the rest with a pheromone secreted from the Dufour's gland in her abdomen. With the worker opposition liquidated or dispersed, she grabbed the *Formica* queen and, for twenty-five minutes, bit her repeatedly in the head, thorax, and abdomen. The *Polyergus* queen's assault is so rapid and formidable that the *Formica* queen can only muster a feeble and futile counterattack. Through the microscope, I could clearly see that between bouts of biting, the attacking queen opened her mandibles wide and, extending her hypopharynx (tongue), continually licked the dead queen's wounds.

Within minutes after the death of the *Formica* queen, the small nest underwent a remarkable transformation. The remaining *Formica* workers behaved as if they were sedated. They calmly approached the *Polyergus* queen and began grooming her as she assembled the scattered *Formica* pupae into a neat pile, and triumphantly stood on top of it. At this point, the colony takeover was complete.

But how did the *Polyergus* queen bring about this dramatic shift in the behavior of the *Formica* workers? Social insects use chemicals, called pheromones, to communicate with one another. Pheromones are similar to hormones, in that both are secreted by glands. But whereas hormones are secreted into the circulatory system within an organism, pheromones are excreted to the outside and affect the behav-

ior of other organisms. One possibility was that naturally occurring pheromones of the *Polyergus* queen were similar to those of the *Formica* queen. If so, she would have been using what ecologists call chemical mimicry to accomplish her takeover. But because the invader was accepted only after she killed the host, I was drawn to an alternative hypothesis, one that I call the "chemical heist." In this view, the *Polyergus* queen acquires chemicals from the *Formica* queen during the very act of killing and licking her.

We repeated the original experiment, introducing a *Polyergus* queen to a *Formica* nest with workers, pupae, and queen, but with a twist: we had already killed the *Formica* queen by rapidly freezing and defrosting her. The chemical heist hypothesis predicted that the *Polyergus* queen would still have to attack the dead host queen, pierce her exoskeleton, and ingest her body fluids. The results were exactly as we had predicted. Upon entering the nest, the *Polyergus* queen ran past the attacking workers, pounced on the motionless *Formica* queen, and proceeded to bite and lick her just as if she were alive. After about twenty minutes of working over the *Formica* queen, the *Polyergus* queen was groomed by the *Formica* workers and accepted by them as their new queen. Apparently the pheromones of the dead queen, and not her murder, triggered the remarkable transition.

To determine whether the chemicals acquired from the dead *Formica* queens are long-lasting, we repeated the experiment, but removed the *Polyergus* queen as soon as she had finished killing and licking her victim. We then placed the queen in a vial for seven days before reintroducing her into a nest of *Formica* workers and pupae. Despite her lengthy absence, she was immediately accepted by the *Formica* workers, who approached her slowly, waved their antennae over her and commenced grooming. We saw no signs of aggression.

One question remained: How does a *Polyergus* queen know which species of ant to parasitize? Many ant species inhabit southeastern Arizona, and a newly mated *Polyergus* queen might easily encounter the nests of more than two dozen species in a single afternoon. But only one will do. Choosing the proper host is crucial because worker ants do not alter their behavior as a result of being parasitized.

Inside a *Polyergus* nest, *Formica* workers forage for the same food (nectar and dead arthropods), construct the same galleries, and defend their colony against the same predators that they do in their own

A Polyergus *worker, left, carries the pupa of a* Formica *ant. Upon emergence from the pupa, the young adult will join the workforce in the new, mixed-species nest. Below: Young* Formica *ants emerge from their cocoons. Within a few days, they will acquire adult pigmentation.*
Both photographs by Howard Topoff

nests. Even if a *Polyergus* queen were somehow able to become adopted by a small colony of harvester ants, it's a good bet that the workers would continue to bring their choice food, seeds, back to the nest. Since neither the *Polyergus* queen nor her larvae could survive on this high fiber diet, such a mixed-species nest would quickly perish. Successful parasitism thus dictates that parasite and host species share an extraordinarily similar ecology, which probably explains why socially parasitic ants and their hosts are often closely related taxonomically.

I tackled this question in the pine barrens of Long Island, New York, where *Polyergus lucidus* (the eastern species of this genus) uses at least three species of *Formica* as slaves. Each *P. lucidus* colony, however, enslaves only one of these three types of *Formica* ants. Linda Goodloe, one of my graduate students, surveyed *P. lucidus* colonies in late summer, when mating flights occur. For several days prior to flying, winged queens emerge from the nest in late afternoon and join several hundred workers milling around the nest entrance. We captured queens from *Polyergus* colonies containing *F. schaufussi* or *F. nitidiventris* slaves, cooled them to immobilize them long enough to dab a streak of enamel paint on their abdomens, and then immediately returned them to their home nests.

For the next few weeks, we watched the ground near the colonies for the presence of marked queens that had recently mated (indicated by the absence of wings). We recaptured thirteen painted *Polyergus* queens from colonies with *F. schaufussi* slaves and brought them to the laboratory, where we presented them with a choice of two host *Formica* species: *F. schaufussi* (the species from their home nest) and *F. nitidiventris* (with which they had no previous experience). All thirteen queens selected colonies of *F. schaufussi* to invade.

We were only able to recapture one painted *Polyergus* queen from a *F. nitidiventris* colony, but given a choice of nests to invade, it chose a colony of *F. nitidiventris*. *Polyergus* queens use a very simple rule: invade any colony containing the same species of host ant that was in the nest in which you were raised. Such specialization probably increases the chances that *Polyergus* queens will be able to find compatible hosts.

But for such parasitism to have evolved, an occasional *Polyergus* queen must have invaded the nest of an unfamiliar species. Imagine a lone, newly mated *Polyergus* queen, scurrying around the field, sticking her nose (actually her antennae) into crevices and under rocks, looking for the nest of a foreign ant species to assault. Sound dangerous? In addition to sheltering a wolf spider, sun scorpion, or centipede, any nook or hole might harbor a colony of carpenter ants whose powerful jaws could instantly decapitate an intruder. Undoubtedly, *Polyergus* queens often ended up as tasty morsels for other arthropods, but a few must have been successfully adopted by a new host species.

To see how *Polyergus* queens might react if given the opportunity to acquire the odor of an unfamiliar *Formica* queen, we returned to Arizona. At an elevation of 8,200 feet, in a forest of ponderosa pine and Douglas fir, *Polyergus* ants raid nests of *Formica occulta* for slaves; at lower elevations, they parasitize *F. gnava*. We collected seven colonies of *F. occulta,* and set them up in laboratory nests. Into each *F. occulta* nest, we introduced a newly mated *Polyergus* queen from a colony found at the lower elevation and that therefore contained *F. gnava* slaves.

The results of the seven trials were mixed. Five of the *Polyergus* queens showed no interest in attacking the *F. occulta* queens; they encountered the foreign queens, brushed them with their antennae briefly, and then ignored them. Attacking *Formica* workers killed three of these passive *Polyergus* queens. The other two queens escaped harm by quickly leaving the nest. Remarkably, two of the seven *Polyergus* queens did seize and kill the foreign *Formica* queen. And when they finished licking their victims, both were promptly adopted by the foreign *Formica* workers.

While this success rate might seem poor, the payoff for *Polyergus* is large. Indeed, social parasitism is such a successful adaptation that it has arisen independently in many unrelated animals, including fishes, birds, and insects. Among fishes, only the most rudimentary form of brood parasitism exists, in which the parasitic female's role ends after egg laying. Females

Raymond A. Mendez

A Polyergus *queen, right and below, usually mates during the a slave raid. Having emitted pheromones to attract the darker, smaller males (below left), the queen mates with one, and after removing her wings, continues with the raid.*

Howard Topoff

of the Asian freshwater minnow *Pungtungia herzi*, for example, deposit their eggs on the same aquatic reed as their host, the perch *Siniperca kawamebari*. Because male *Siniperca* don't discriminate between the two types of eggs, they end up guarding the parasite's eggs along with their own. When the minnow eggs hatch, the parasitic fish assemble with others of their own species and have no further contact with their hosts.

Cuckoos, by contrast, carry brood parasitism several steps further. After depositing an egg in the host's nest, a female cuckoo removes one of the resident eggs. Egg mimicry is also common, so that a cuckoo specializing in meadow pipits lays brown, spotted eggs; while a cuckoo specializing in reed warblers lays greenish eggs. The cuckoo chick enhances the parasitic relationship by hatching first and systematically ejecting the eggs and newly hatched chicks of the host. The host parents clearly do not recognize the deception, and they feed the parasitic chick until it is ready to leave the nest. Like the minnows, however, fledged cuckoos promptly rejoin members of their own species, and have no further interactions with the host species until they are reproductively mature and ready to parasitize another nest. How does the female cuckoo choose an appropriate host to parasitize? Apparently, she uses the same rule as a *Polyergus* queen. The cuckoo lays her egg in a nest containing the same host species with which she was raised immediately after hatching.

My daughter's fourth-grade science book does a pretty good job illustrating the major principles of ecology. On evolutionary diversity, however, it falls short. Like most biology textbooks, it echoes the fantasy that vertebrates are higher on the evolutionary tree than invertebrates, and are therefore more complex in both structure and function.

Yet the behavior of *Polyergus* queens during colony founding offers perhaps the best illustration that the evolutionary process yields a mosaic of species—often with unique and extremely sophisticated social adaptations—and is not an escalator leading methodically and inexorably to ever greater complexity. Ant societies, with their behaviorally specialized castes, elaborate systems of chemical communication, and huge potential for adjusting to ever changing environments, have evolved levels of social organization that far exceed even those of most vertebrate species. □

S. R. Maglione; Photo Researchers, Inc.

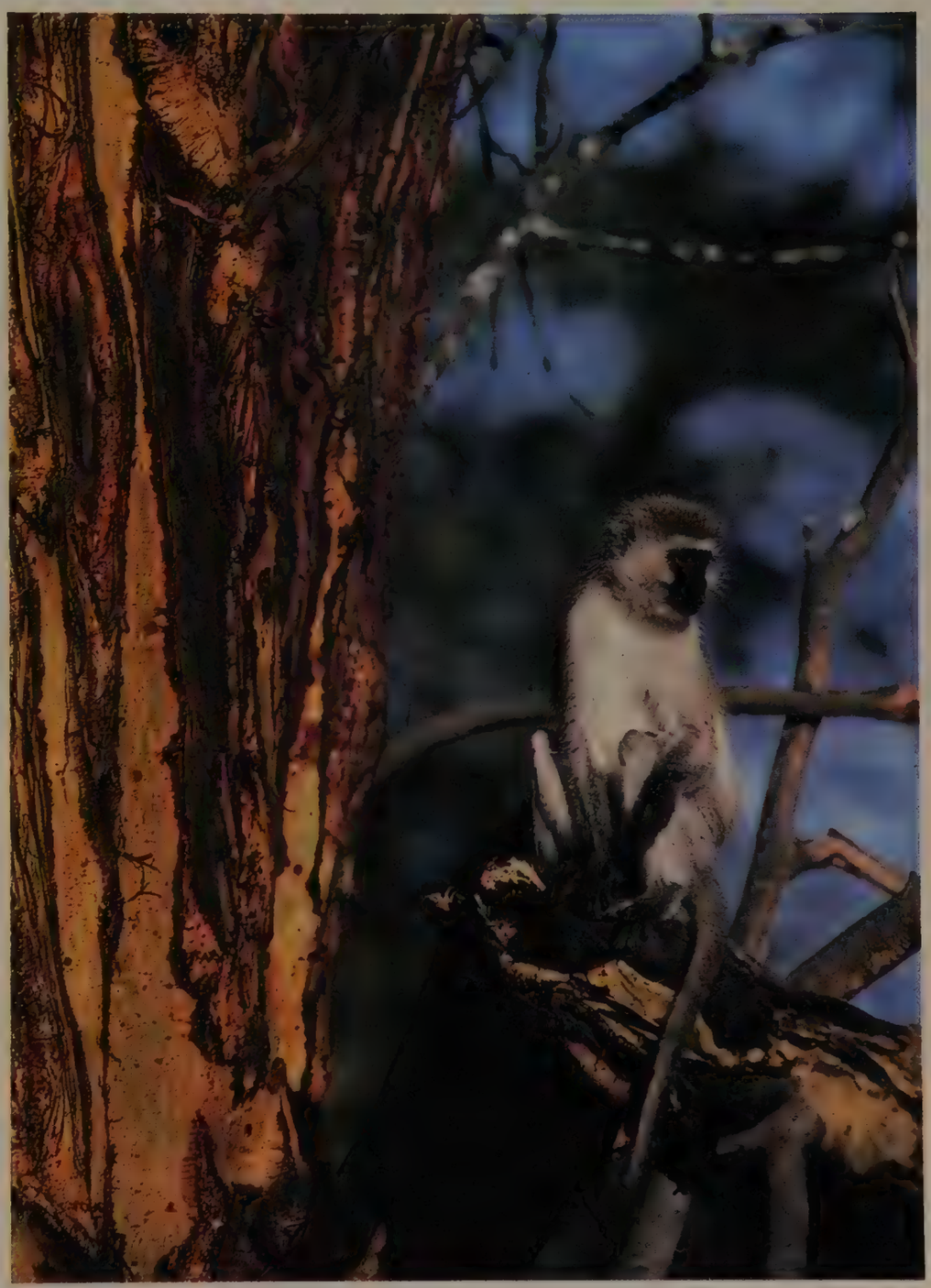
The Vervets' Year of Doom

Can Amboseli's monkeys survive the predation of leopards and the loss of their favorite trees?

by Lynne A. Isbell

The sky is clear in Amboseli National Park, Kenya, and Mount Kilimanjaro rises to meet it. On the plain, Newton, Charing Cross, Gorbachev, and the rest of the group of vervet monkeys stir from the sleeping tree to begin another day of eating, arguing, and grooming one another. Newton, an adult female with a distinctive white moustache, directs her attention to a large *Azima* bush sixty feet away that is thick with ripe berries. Approaching the bush could be risky, as the dense foliage might harbor a leopard or python. She scrutinizes the greenery for a long time, then climbs down the sleeping tree and passes by several smaller bushes, turning over elephant dung along the way to look for juicy insects. Suddenly, a blur of colors darts out from behind one of the bushes. Within seconds, a leopard grabs Newton by her neck, breaking it instantly. Charing Cross, witnessing the kill, emits a rapid series of sharp barks. To the vervets, its meaning is clear: "LEOPARD! LEOPARD!" The call is quickly taken up by the rest of the group as other individuals on the ground race up the nearest fever trees for a safe view. The cat carries Newton's body to a shady spot beneath the dense branches, where it consumes the meat. Charing Cross, Gorbachev, and the others will never see Newton again.

Anyone who visits the numerous national parks in East Africa quickly learns that dangers abound there. Parched bones liberally litter the ground. Many belong to gazelles, wildebeests, and other ungulates taken by lions, hyenas, cheetahs, and leopards. Some smaller animals, however, leave very few bones behind to remind us that they were once dynamic individuals that maneuvered their way around friends and enemies in an attempt to survive and reproduce. Vervet monkeys are the size of



An infant vervet clings to its mother, opposite page, in Kenya's Amboseli National Park. Vervets prefer to sleep in fever trees, above, whose many vertical branches may deter leopards from climbing them.

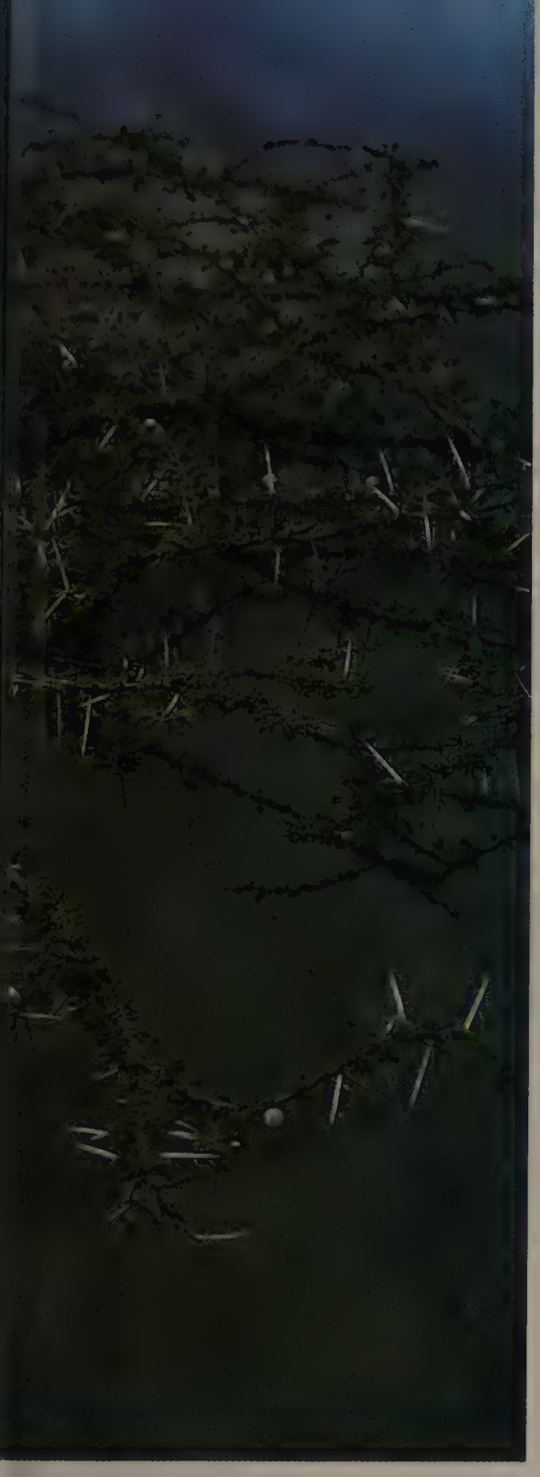
Mary Ann McDonald

domestic cats; when they are eaten by carnivores, particularly leopards, virtually nothing remains.

Although vervets are found throughout sub-Saharan Africa, they are restricted to savanna–woodlands habitat along rivers, lakes, and swamps. They live in cohesive groups, ranging in size from two to about twenty adult males and females, with accompanying juveniles. Following the typical pattern for Old World monkeys, female vervets usually live and die in their mother's group, while males leave to join other groups when they reach sexual maturity at five or six years of age. Females form the core of a stable but competitive social environment, and their relationships are strictly hierarchical. Whenever a conflict arises over food, grooming partners, or even seating locations on a branch, the highest-ranking female and her daughters can push everyone around, while the lowest-ranking female and her daughters must give way to everyone. Because males are more transient than females, their place in the hierarchy is less fixed and less dependent on kinship.

Researchers have studied Amboseli vervets for three decades, during which they have learned about the kinds of foods vervets prefer during good times and bad, the role of kinship in gaining access to those foods, and how the animals steer clear of danger. Zoologist Tom Struhsaker first recognized that vervets in Amboseli give different alarm calls to different predators, documenting a vocabulary of sorts. Later, Robert Seyfarth and Dorothy Cheney systematically studied the vervets' responses to these alarm calls (*see* "In the Minds of Monkeys," *Natural History,* September 1990). After recording alarm calls, Seyfarth and Cheney played them back to the vervets when predators were absent. When vervets on the ground heard the "snake" alarm, they stood on their hind legs and scanned the ground. When they heard "eagle" alarm calls, they dashed into bushes for cover. And, as on the day that Newton died, when vervets heard "leopard" alarm calls, they retreated quickly to the upper branches of trees.

Predation is a fact of life for vervets. They are vulnerable to pythons, eagles, leopards, and even baboons. Still, when I first went to Amboseli in 1986 to study the vervet's social system, I did not expect to witness the near annihilation of the entire study population. When I arrived, the vervet population consisted of seventy-six



Renee Lynn; Photo Researchers, Inc.

At Lake Nakuru National Park in Kenya, a young vervet maneuvers through an acacia's thorny branches, left, to reach the small, edible white flowers. At the approach of a large python in Amboseli, below, vervets stand on their hind legs while excitedly repeating their "snake" alarm calls.

Richard Wrangham; Anthro Photo

individuals living in six groups that were well habituated to human observers. Indeed, these vervets usually treated us as if we were just another species of gazelle—a neutral species, neither beneficial nor harmful. By the time my study ended more than two years later, the original population had been reduced by two-thirds, to twenty-five individuals in three groups. When I returned in 1992, only two small groups, totaling nine individuals, still remained. What happened to the luckless Amboseli vervets, and can their devastated population survive?

Struhsaker, who in the 1960s was the first scientist to study the Amboseli vervets, found upon returning there in the 1970s that the population had declined. He noticed, too, that there had been a decline of the fever trees, *Acacia xanthophloea,* on whose sap and seeds the vervets feed. The monkeys also use the trees as nightly roosts, descending each morning to forage for berries, insects, and other delicacies. (Fever trees grow quickly but live perhaps only 100 years. And as ecologists Truman Young and Keith Lindsay have pointed out, stands of fever trees usually contain individuals of similar age. Since the trees are aging simultaneously, they die within a few years of one another.) As their food supplies gradually dwindled, so did the monkeys. By the time of my study, however, the last of the fever trees had begun to die, dramatically affecting the lives of the remaining vervets.

As their responses to alarm calls attest, vervets also use fever trees for shelter, primarily when fleeing leopards. About six months into my study, I began to suspect that something unusual was happening after Newton and five juveniles from her group disappeared on the same day. The vervets seemed to be disappearing at a faster rate than in past years. Often, they simply vanished overnight, despite my extensive searches for signs of them. When I did find evidence, it was largely circumstantial. Animal tracks are easily seen in Amboseli's dust, and I sometimes found clues that told of vervets darting out of their sleeping tree in the middle of the night and of a leopard among them. I could easily imagine the terror of the monkeys when they were startled awake by the big cat. Once I found something more substantial: the lower jaw and a clump of hair belonging to Tycho, a low-ranking female who was ten years old at the time of her death. Near her fragmentary remains were leopard tracks and the only pile of leopard dung I ever found in Amboseli.

At about the same time that the vervet population was rapidly shrinking, I began to see leopards more often than observers had in the past. In 1987, I saw leopards nineteen times, sometimes even without the help of the vervets' alarm calls. During the entire previous year, vervet researchers had observed a leopard only once. One of my sightings was an adult female with two cubs. Judging from the tracks I saw under the vervets' sleeping tree the morning Almond Joy and her four-year-old son, Hoola Hoop, disappeared, the female leopard had been hunting that night with at least one of her cubs. Twice I saw an adult female and an adult male leopard together, although most often I saw a lone adult male. Leopards live solitarily when they are adults, and because adult males do not share home ranges, I believe that my sight-

Carol Hughes; Bruce Coleman, Inc.

Vervets eat a wide variety of seeds, fruits, flowers, sap, and insects. An adult in South Africa feeds on flame creeper blossoms, left. Below: An infant that has wandered a few feet away from its mother peers through the foliage in Nairobi Park, Kenya.

Erwin and Peggy Bauer

ings were all of the same individual.

Sometimes the vervets' alarm calls and the directions in which they gazed led directly to my leopard sightings. Even so, I was not always able to see the predator that stirred the monkeys. While vervets are undoubtedly better at detecting leopards than I am, at times they also missed seeing the predator—with unfortunate results. Even though the number of observed alarm calls had risen sharply over previous years, the disappearance rate for vervets shot up to 65 percent in 1987. That was the year of vervet doom. During the ten previous years since Seyfarth and Cheney began the long-term project, the yearly average of "disappearing" individuals had been only 22 percent of the population. The increase in my sightings of leopards, the greater frequency of the monkeys' alarm calls, and the increase in such alarms during months when most vervets disappeared all pointed to sharply increased predation by leopards.

My frustration at not actually observing the cause of the vervets' disappearance was exacerbated by what Seyfarth and Cheney have informally labeled "the Nairobi effect," referring to what seemed to be an increased tendency of vervets to disappear while observers went on short trips to the Kenyan capital for supplies. (Fewer monkeys, it seemed, disappeared during the many weeks that fieldworkers remained in Amboseli.) But the Nairobi effect had been difficult to document over the years, partly because predation, although high relative to other primate populations, was still rather uncommon. Also, the behavior of other predators, such as pythons and martial eagles, was unaffected by the presence or absence of humans. With the dramatic increase in leopard predation during my study, however, ecologist Truman Young and I were able to show that the Nairobi effect was real.

At the beginning of my study, I saw leopards only rarely. When I returned from trips to Nairobi, however, vervets were nearly four times more likely to have disappeared than while I was present. Whenever I came back from the city, the leopards apparently took a couple of days to recognize that I was back to stay for a while because I saw them more often in the first two days after returning than at any other time. A ranger station on the edge of the study area had a similar effect in inhibiting the leopards; the closer the vervet groups lived to the ranger station, the fewer losses they suffered.

Then something changed. Eight months into the study, my presence apparently no longer handicapped the leopards. Both leopard sightings and vervet disappearances increased dramatically, and vervets were no more likely to disappear during my trips to Nairobi than during my field days. My guess is that the male leopard was seeing me so often that he was becoming progressively less wary. In the early days, he ran away the instant we saw each other. In later months, he simply walked away whenever I arrived. Finally, on my last day in the field, I felt as though he had granted me a supreme honor when I watched him for over an hour before he casually yawned, stretched, and then ambled down from a tree in which, on many other nights, vervets slept.

Why had leopard predation become more intense during my study than during any of the previous years of continuous research on Amboseli vervets? One explanation is that the increase in predation was a rare event, directly related to the loss of the fever trees, which had provided much of the vervets' food and shelter. Another possibility was that the short-terrm increase in predation was just another in a series of blips that have occurred repeatedly throughout the thousands of generations in which vervets and leopards have coexisted. Both explanations are likely to be partly correct.

This sudden rise in predation was probably an important event in the lifetimes of individual vervets—or researchers— but a common event in the evolutionary history of vervets as a species. In this case, we don't know whether the local leopard population had grown, whether a few were spending more time in the area, or whether a new individual with a decided taste for vervets had moved into the neighborhood. What we do know is that leopards caught more vervets and that at least part of the reason was the loss of the monkeys' favored fever trees.

As the groves of fever trees died, the vervet groups that had lived in the same small home ranges for generations began moving into new and unfamiliar areas. Between 1986 and 1988—with the year of

Stan Osolinski; Oxford Scientific Films

Bearing her youngster on her back, a female vervet, below, feeds on ground plants in Amboseli. Opposite page: In Kenya's Samburu National Park, a leopard carries a vervet it has killed. Leopards usually seek a secluded spot or sturdy branch where they can feed undisturbed.

Erwin and Peggy Bauer

vervet doom in the middle—we observed groups shifting their home ranges away from the dying fever trees and into the drier but healthier woodlands of *Acacia tortilis,* the umbrella tree. Vervet groups are aggressively territorial in Amboseli and do not share their home ranges with other groups. As the largest group moved into the umbrella tree woodlands, it drove out two smaller, neighboring groups that had been established there. These smaller groups were driven farther into umbrella tree woodlands where no other vervets lived.

The largest group gained access to three times as many trees as it had previously occupied; whereas smaller troops were forced to subsist on more limited resources. Regardless of the number of trees that any group acquired or lost, vervets were more likely to disappear when they moved into new and unfamiliar areas.

Many zoologists believe that animals benefit in some way from living in a familiar place. Most animals do not simply wander around randomly over the earth but instead use a much more limited area, their home range. Among mammals, vervets included, females tend to remain in the area where they were born, while males tend to disperse into new areas before settling down. On familiar ground, animals may benefit by knowing where to find food and shelter and by becoming adept at anticipating the behavior of familiar predators and conspecific competitors.

The cost of living in unfamiliar habitats showed itself in another way. Three of the six original vervet groups became so small as a result of predation and decreased reproduction that the straggling survivors abandoned their home ranges and joined neighboring groups. During the first six months of joining new groups, newcomers were more likely to disappear than the long-time residents who were familiar with the same habitat. Apparently, each newcomer has to learn about the new environment through direct experience; little, if any, of the residents' knowledge seems to be communicated. With time, however, any difference in mortality between newcomers and old hands declines steadily, as familiarity with an area appears to reduce an individual's vulnerability to predation.

The value of living in familiar surroundings has always made good intuitive sense. Our study, however, has documented its value in minimizing the risk of predation. Danger from such predators as leopards, however, must be viewed against the larger background of ecology and cycles of vegetation.

If the fever trees had not died, Tycho, Almond Joy, Hoola Hoop, Newton, and more than thirty others might be alive today. Unlike umbrella trees, which grow slowly but live several hundred years, fever trees don't live very long. Long-term research in Amboseli suggests that vervets are intimately tied to the fever tree population's cycle of growth and death. When the trees are middle-aged and healthy, they provide vervets with abundant food. Vervets take advantage of this, reproducing every year. As a result, their groups may become large during the boom years. When the fever trees begin to die, however, females do not have enough food to sustain their high reproductive rates. Over time, vervet groups become smaller as older individuals are not replaced by younger ones. The final stage of decline may occur when the last of the fever trees die and vervets are forced to move into unfamiliar habitats. Vervets become even more vulnerable to predation than before, and if leopards are around to take advantage of the situation, vervet mortality increases until the monkeys become familiar with their new locations.

Newton didn't survive the change, but she left relatives to carry on. Her daughter, Nut Case, and a few individuals are managing to live and reproduce in the umbrella tree woodlands. As a species, vervets may be very good at surviving as long as there are alternative trees available for food and shelter. If the Amboseli ecosystem is not disturbed and fever trees eventually regenerate, Newton's descendants may one day venture into new fever tree woodlands and experience a new population boom. This dynamic cycle involving fever trees, vervets, and leopards may have been played out over and over throughout their coexistence in East Africa. Newton's ancestors probably faced the challenges she failed to meet, and her descendants may be faced with similar challenges one hundred years from now when a new crop of fever trees becomes old and dies in Amboseli. □

In the hot, dry Negev Desert highlands, snails venture out mostly at night, when the air is cool and the rocks they feed on are covered with dew.

Desert Snails' Daily Grind

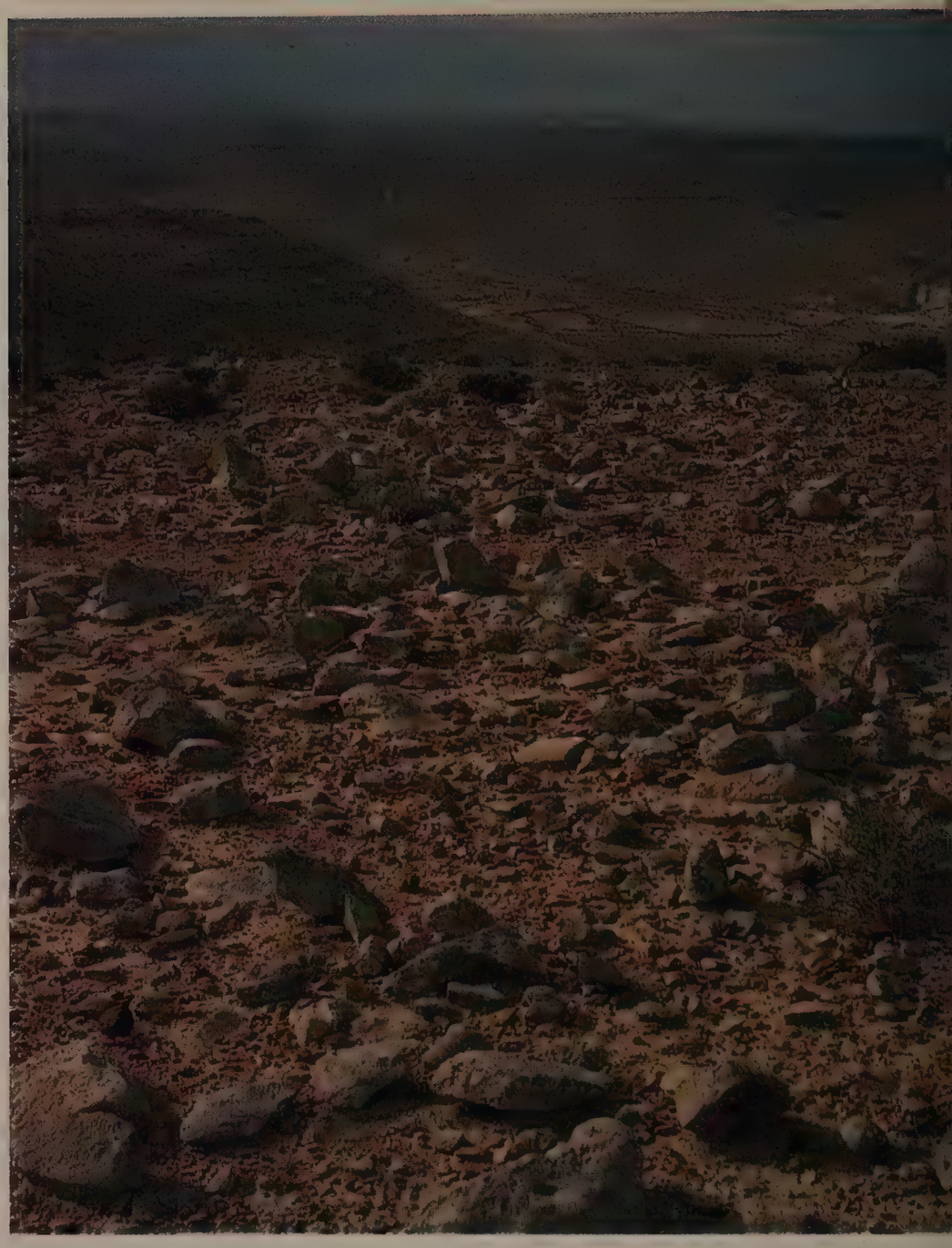
In scraping out a living on the rocks, small mollusks make a big difference to the Negev

by Clive G. Jones
and Moshe Shachak

Photographs by
Jeffrey L. Rotman

Apart from a sprinkling of shrubs, the steep, treeless slopes of Israel's Negev Desert highlands seem devoid of life. But just beneath the surfaces of the limestone outcrops, rocks, and small stones that cover much of these hillsides, there is abundant life. Countless communities of lichens—symbiotic associations of algae and fungi—thrive in the spaces between the rock particles. Here they are protected from extremes of temperature and humidity and yet are close enough to the surface to get enough sunlight for photosynthesis.

Among the most striking features of the rocks in the Negev highlands are the white lines—actually gouges about one-half to two millimeters deep—that meander between and around the lichen colonies. These lines—sometimes so numerous that they form a lacy, filigree pattern—were long thought to be the work of the various species of lichens as they competed for living space or extracted nutrients from the



rocks. Recent research, however, has turned up a very different sort of explanation and revealed an unappreciated major player in the Negev ecosystem.

In 1986, while investigating the lichen communities, we became intrigued by the gouges and began to suspect that they had been cut by an animal. Particularly tantalizing were the many slime trails—the characteristic sign left by snails on the move—that we saw on the rocks. We turned our attention to the three closely related species of small snails, *Euchondrus albulus, E. desertorum,* and *E. ramonensis,* that we found living under the rocks in the Negev.

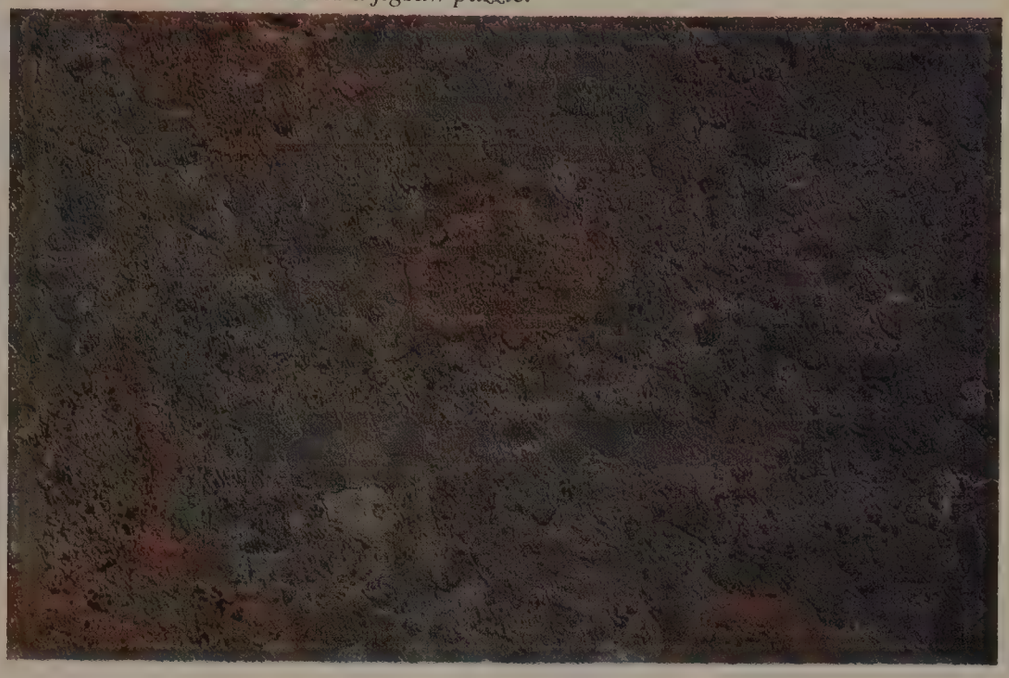
To observe the little snails (no more than one centimeter long), we set some up in our laboratory with rocks and appropriate water, light, and temperature regimens. We soon noticed that when the snails traveled across the rock surface, they stopped every so often, shifted to a more upright position, and began to sway back and forth. After twenty minutes or so, they moved on, leaving behind a new white scar in the rock about ten millimeters long, one millimeter wide, and one-half millimeter deep. A closer look revealed that the snails had gouged the rock, apparently to get at the layers of green algae and fungi, and in the process had left behind a white scar the color of exposed limestone. We later found that the snails were actually consuming the rock—as well as the lichens within—but were digesting only 5 percent of what they had eaten. Most was excreted in small coils of powdered rock and undigested lichens.

Like many other snails, the Negev's *Euchondrus* snails can handle a tough diet because they are equipped with a toothed, tonguelike organ, the radula, that can be scraped back and forth like a file. The snails break a lot of teeth on the rocks, but the radula grows continuously from the back of the mouth, replacing the worn-out and broken teeth at the front. (Somewhat surprisingly, these snails do not have special orthodontic adaptations. Unlike predatory marine mollusks that drill through the hard shells of other mollusks, the teeth of *Euchondrus* snails are not especially thick, nor do they appear to contain iron or other hard metals.)

The rock-eating habits of these snails went undiscovered for so long primarily because the snails hide, immobile, under the rocks during the heat of the daytime and only come out to forage at night and early morning, when the rocks are covered with dew (and when biologists are usually absent). During the cooler seasons, the daytime temperature ranges from 40° to 60° F, while at night it gets as cold as 22° F. So from September to April, on an average of 210 nights a year, dew forms on the rocks as they cool down at the end of the day and keeps them wet until the sun evaporates the moisture the next day. Equivalent to thirty millimeters of rain annually—in a desert that only receives an average of a hundred millimeters of rain each year—the dew is critical to the survival of both lichens and snails. Dew provides the water used in lichen photosynthesis, cools and lubricates the rock surface, and replaces the water lost by the snails in the slime trails they leave behind as they forage over the rocks.

About sunset, the snails start to move out from under the rocks. But before climbing up for a night of foraging, they defecate the indigestible remains of the previous night's meal. It takes them just a few minutes to climb up the rocks, and once they are out in the open, the snails feed until the rising sun heats the air and the dew begins to evaporate. Then they disappear under the rocks again to digest their food. At summer's height, from May to August, it gets as hot as 95° F during the day and 60° to 70° F at night. Dew cannot form, so the snails aestivate under the rocks, sealing themselves in their shells by forming a special, hard operculum, or

Beyond this rocky slope, left, lies a dry river bed, with more of the Negev Desert highlands visible in the distance. Countless lichens live just beneath the surface of the many rocks that litter the ground. Below: A rock is covered by subsurface lichen colonies, as well as a few blotchy patches of brownish surface lichens. Feeding snails have cut so many white grooves into the rock that it resembles a jigsaw puzzle.



plug, over the shell opening. They do not feed at all.

Much of the time, the snails are homebodies, seldom straying from their rock. But from November through April, whenever rain makes the soil wet enough for travel, the snails become more adventurous. After a rain, the patches of soil between the rocks are filled with dozens of snails moving to-and-fro, changing rocks, mating, and laying their eggs in the moist earth.

The more we poked around after the snails, the more we realized how many there were. They were most conspicuous during their rainy day journeys of a few centimeters to a few meters from rock to rock, but even when they weren't out and about, a minimum of effort on our part revealed impressive numbers. Almost every overturned rock exposed one or two snails—about twenty per square meter. That so many snails were able to make a living eating rocks in the desert is somewhat surprising, since snails are usually found in moister, cooler climates eating leaves or detritus. The snails, we were to learn, have an ecological significance in the workings of the Negev Desert that goes well beyond their unexpected abundance and unusual eating and toilet habits.

Of major importance is their effect on the lichens living within the rocks. Windblown lichen spores land on new rocks, germinate, and grow to form colonies that eventually fill up all the space between the rock particles just under the surface. Any further lichen growth depends on the snails. By removing the top layers of rock, the snails expose fresh rock—and also minerals that the lichens need. The grooves made by the feeding snails collect dew and nitrogen-containing dust, both critical resources for lichen growth. However, in the long term, the myriad white trails on the rock surface may increase the albedo, or reflectance properties, of the rock, slowing the rate at which the rock heats up and cools down, and perhaps reducing the amount of dew that forms.

Snails usually feed at the periphery of lichen colonies, which range in size from about one-half to three centimeters in diameter and where most of the nitrogen-rich new growth is to be found. As the snails cut new trails in the centers of colonies, they stimulate regrowth. They thus determine the size, shape, and number of lichen colonies. They probably also affect the species composition of the lichen community by selectively feeding on some colonies, encouraging regrowth of those best able to tolerate continual grazing. Snails may even help lichens that live within the rock outcompete surface-growing forms. The surface species, common on rocks ungrazed by snails, but far less abundant on grazed rocks, block sunlight, ultimately killing any lichens living within. Perhaps the disturbance of the rock surface by snails and the vigorous regrowth of internal lichens following grazing help prevent the surface lichens from establishing a foothold.

Like cows in a field, however, snails can overgraze. If there are too many snails on a rock and no rainfall to allow them to disperse, the snails will cut more and more new trails and graze less and less in old trails. Eventually the food runs out, and the snails must go quiescent (sometimes for as long as a few weeks) or die. While not common, overgrazed rocks covered with hundreds of white lines can be seen throughout the Negev, particularly in the areas with the least rainfall.

To gouge out the rock, facing page, and get at the lichens within, a snail extrudes its head and scrapes at the rock with its powerful, toothed, tonguelike radula. Below: After a night of feeding, a snail retreats under rock, where it excretes little coils of undigested rock and lichens (right and left).

The impact of the snails, however, goes well beyond the Lilliputian world of the lichens. These tiny mollusks are responsible for most of the new soil—in the form of their little fecal coils of powdered rock—that forms in the Negev each year. Annually, the snails graze from 4 to 7 percent of the total rock surface area to a depth of one millimeter or so, turning about 800 pounds of rock into soil per acre of desert. The Negev also receives soil blown in from the Arabian and Sinai Peninsulas, and until the discovery of the snails' activities, such aeolian deposition was considered to be the major source of new soil in the desert. But wind brings in only between 220 and 420 pounds of soil per acre each year, considerably less than the snails' contribution.

The snails do not just create soil; they also fertilize it. Desert environments are generally low in nitrogen, the element that is considered to be the second most important factor (after water) affecting the growth and productivity of higher plants. Foraging snails seek out lichens with the highest nitrogen content, but do not use all the nitrogen they consume. About 5 percent of the dry weight of snail feces deposited under the rocks is nitrogen. These tiny contributions add up: Our calculations indicate that snails transfer about three pounds of nitrogen to each acre of desert soil every year. The most common snail in the area, *E. albulus,* is responsible for 11 percent of all the nitrogen that enters the soil annually, an impressive amount for a single species.

Rain, dust, and the nitrogen-fixing activities of blue-green algal crusts on the soil surface also contribute nitrogen to the desert soil, but much of it is lost when wind erodes the topsoil and rain washes it down from the rocky slopes to the wadis, or temporary rivers, in the valleys below. Snail-produced nitrogen, deposited under the rocks, has more staying power because it is protected from runoff and wind erosion by the rocks and by small dams of soil that form at the base of the upslope side of the rocks. Patches of earth between the rocks support a rich variety of annual plants and woody shrubs. There, the plant roots have access to both the pellets of snail fertilizer and to water that has deeply infiltrated the soil. The growth of plants appears to benefit from the snail fertilizer.

The snails of the Negev Desert are not unique. In the 1920s, similar snails were discovered in the Dolomite Alps of southern Germany, where they also feed on subsurface lichens. Their rock-eating habits, however, were not recognized until our discovery in the Negev. Local alpine geologists can now explain the strange, grooved patterns on the rocks, for which they had previously invoked geomorphological explanations.

Interestingly, both the alpine and Negev species are distributed along the ancient limestone deposits that predate the formation of the Mediterranean Sea. These deposits run south from the Alps in southern Germany, through Italy, and down into the Mediterranean regions of the Middle East. Rock-eating snails may thus have evolved a long time ago and have been eroding and fertilizing both the deserts and mountains for millenniums, even though a sea now separates the regions.

Deserts are harsh environments, where animals as small as snails might be assumed to live at the whim of the elements and to play a limited role in the workings of the ecosystem — perhaps eating a few plants and animals and, via their own death and decay, making a minor contribution to the cycling of nutrients. The rock-eating snails of the Negev, however, have shown this is not a sound assumption. By controlling the growth, productivity, and composition of endolithic lichens, by turning rock into soil, and by then fertilizing that soil, they join the ranks of the desert's other natural engineers.

Porcupines in the Negev dig up and eat the bulbs of some desert plants and, in doing so, make pits in the soil that trap water runoff and seeds, creating ideal habitats for diverse annual plants. Desert isopods, or pill bugs, dig burrows seventy centimeters deep to get down to water, bringing infertile, salty soil to the surface, where it erodes and washes away. Altogether, these creatures have a major effect on their desert environment, albeit less dramatic than the large-scale consequences of the dam building of beavers and less familiar than the improvements to soil fertility and aeration provided by earthworm digging (to which Charles Darwin devoted an entire book). Without the activities of the snails and other ecosystem engineers, the earth would be a much less diverse, fertile, productive, and interesting place. □

Beastly Thinking

by Richard W. Byrne

We are currently seeing a spate of books on animal minds. Even to utter the words "animal mind" used to be considered a near-mortal sin for anyone in the behavioral sciences. Nowadays, however, people even title books with the words. What has been happening?

Twenty years ago, scientists could be neatly divided into two types by their response to the question, "What do you imagine happens inside the minds of animals?" Comparative psychologists, behaviorists, and (to a large extent) ethologists would enthusiastically describe rigid, inflexible, mechanistic goings-on—like the machines that controlled those early sci-fi automatons of 1950s movies. Other scientists—and really everybody else, scientist or not—would reply: "Simple thoughts, I suppose, but I don't see how we'll ever know."

How were the professionals who worked on animal behavior so sure of their answers? They weren't, of course, but they were carefully following the rule that science is supposed to abide by: accepting the simplest hypothesis until there is strong evidence of something more complex. Since evidence was minimal, the automaton theory won out. The various professionals agreed on this but differed about what to do with human minds. Behaviorists denied we had them, or if we did, denied that they had any consequences ("epiphenomenon" is a useful word for something that exists but might as well not, for all the effect it has). Other psychologists generally believed that language had somehow given us minds, on top of animallike reflexes. Ethologists don't study humans, do they? So they kept quiet.

Only cognitive psychologists (a new breed in those days) took the maverick line that minds must be a product of brain processes that are mechanistic and yet not in any way simple, thus managing to offend everybody. (Readers who seek to know a reviewer's bias should know that I was a cognitive psychologist in those days.) Cognitive psychology originally grew from the realization by some people of the implications of computers and artificial intelligence for psychology (a late 1950s conference on "the mechanization of thought processes" had a big impact).

Cognitive psychologists gaily assumed that all human intellect was reducible to machine states and set out to describe complex behavior as the results of software and hardware—of the brain. They did not, however, think 1950s sci-fi efforts

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THE ANIMAL MIND, by James L. Gould and Carol Grant Gould. *Scientific American Library, $32.95; 236 pp., illus.*

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or the behaviorists' theories had much to recommend them. In hindsight, the cognitive approach could have made a bridge between psychologists, impressed with human minds, and evolutionists, who expected continuity between humans and animals. Unfortunately, cognitive psychologists ignored animals.

Donald Griffin set the ball rolling, leading to today's interest in animal minds. Griffin was in an unusual position. He had already made a major scientific discovery, bat echolocation, which somewhat "fireproofed" him from ridicule. Also, he remembered being taught as a student that bats couldn't get around well in darkness. He was not about to accept anyone again telling him that animals couldn't do things.

In 1976 he wrote a book cataloging animal behaviors that are not rigid and inflexible, actions that look suspiciously like our own. He also pointed out that an evolving mind in animals would pay re-

productive dividends, challenging readers to consider the possibility that not all animal behavior is mindless. In this and in subsequent, similar volumes, he inspired a whole generation of researchers, James and Carol Gould among them, to look again at what too many had considered well-worked ground.

The Animal Mind is an attractive volume, taking us on a tour of some of the discoveries these researchers have made. The Goulds' choices hint at some of the attributes that they assume we all agree are "mindlike"—flexible not fixed actions, learned not innate behavior, conscious decisions not unconscious impulses. But do we all agree? Few doubt flexible animal learning, so I was left wondering if they really meant "consciousness" to define mind but hesitated to say so.

The Goulds' own specialty is the honeybee, and many chapters are illuminated by some of the wonders of bee life. Bee behavior is used to convey the message that we must be careful not to attribute our own experiences to animals that may live in a very different world: Seeing ultraviolet and polarization and feeling the earth's magnetism make a bee's world very different from our own. Other species see infrared (pit vipers), hear ultrasonics (bats), or smell so acutely (bloodhounds) that even a footprint translates into a whole creature; we would be rash to assume that their thoughts (if any) are much like ours.

Another important preliminary to serious consideration of animal minds is accepting that flexibility can result from a rigid, innate program of behavior—again well illustrated by bees. Confronted by alfalfa, a plant whose spring-loaded anthers flick pollen onto the underside of big bumblebees, a small honeybee gets a hefty blow. Some learn to avoid untripped flowers or even cheat by forcing their tongues in from the side. Have they understood the

mechanism? Not necessarily. Bees will chew through the side of any flower whose nectar is too deep to reach. In dealing with alfalfa, bees have shown they can learn, but they have only adapted their innate behaviors to a small extent.

Blue tits that broke into milk bottles on British doorsteps to steal the cream provide another example. They learned to tear strips off card tops and, subsequently, to peck through foil caps. But the actions they used are part of a blue tit's normal, innate repertoire; what was learned was simply that doorsteps are a good place to forage. The Goulds spend chapters explaining the widespread innate behaviors of animals and their learning abilities (including innate channeling that makes certain things easier to learn than others), so that readers don't jump to the conclusion that every complex-looking action must imply that the doer has a mind.

The book then goes on to tour the animal kingdom, showing cases that look as if they would be hard for an automaton to cope with—animals acting in ways that look conscious. Perhaps something of a catalog is inevitable in a book obviously intended for a very wide audience, but I found this aspect disappointing; oddly the organization—from insects up to humans—suggests an evolutionary story, but no such case is made. Instead, we are repeatedly shown an action that looks smart, reminded that this "seems to imply" some aspect of mind, and invited to be broad-minded enough to allow that it might.

My favorite is the description of the remarkable flexibility of usage in the famous bee dance, after which the authors are able to say:

> When a human decides whether to recommend a restaurant, taking into account its menu, the tastes of the friends being advised, the cost of the food, the distance to the establishment, the ambience of the dining room, the ease of parking, and all the other factors that enter into such a decision,

The dog in the silent movie The Callahans and the Murphys *was conditioned to cover its ears when music started.*
Courtesy of Culver Pictures, Inc., from *The Animal Mind*

we have little hesitation in attributing conscious, decision-making powers to the calculation. When a small, frenetic creature enclosed in an exoskeleton and sporting supernumerary legs performs an analogous integration of factors, however....

Fair point. The feats of some noninsects sometimes get a less gentle ride.

Chimpanzee termite fishing is "readily accounted for by conventional conditioning," and "all the elements of this tool-use seem prewired," which would surprise the researchers who have, from site to site, studied variations in termite fishing that resemble culture. The spread of "food-washing" in one group of Japanese monkeys is called "unsurprising, given the proclivity of primates to imitate: 'monkey see, monkey do' is as true as it is trite." In fact, the debate rages on as to whether any monkey has the cognitive capacity to imitate at all, and if they could, this would help the case that monkeys have minds, not refute it. But these are small quibbles. Most of the book is accurate and well explained, a pleasure to read.

So is the case made? Animals have minds, it's official. Not quite. Drawing attention to ever-more-convincing similarities of behavioral ingenuity between animals and humans cannot compensate for our lack of understanding of what a "mind" is. The Goulds rightly point out, in a last chapter devoted to humans, that many of our actions are innately guided and a good deal less conscious than we often care to think. But some are conscious, and we have no idea why this is beneficial. We do sometimes think things out but don't know how to detect this ability in other humans, let alone other species. Recently, major strides have been made in clarifying issues, as in Marian Dawkins's *Through Our Eyes Only?* Hers is an outstanding analysis of the possibility of animal consciousness.

But I was left just a little pessimistic after reading the Goulds' excellent book. Is the best we can hope for, as a model of animal minds, perhaps a better class of automaton (with reasonably complex software and powerful hardware)? If so, cognitive psychology of animals will be a growing subject.

Richard W. Byrne is a psychologist with the Scottish Primate Research Group of the University of Saint Andrews in Scotland. His latest book, The Thinking Ape: The Evolutionary Origins of Intelligence, *will be published this fall by Oxford University Press.*

A Lizard Found

by Charles J. Cole

Science often progresses in strange ways, but how often do biologists predict the existence of a species and describe it in some detail prior to its discovery? Not often. Darwin did it. When he saw Christmas Star orchids from Madagascar—white flowers that contained nectar at the bottom of a foot-long shaft—he wondered, "What can be the use of a nectary of such disproportionate length?" Convinced that flowers and their pollinators evolved in tandem, he concluded that "in Madagascar there must be moths with proboscides capable of extension to a length of between ten and eleven inches! This belief of mine has been ridiculed by some entomologists." Forty years later, a yellowish moth with a twelve-inch coiled tongue was discovered on the island and named *Xanthopan morgani praedicta*.

In May 1989, I coauthored an article ("A Lizard Foretold") for *Natural History* that predicted a new species of lizard—one that had never been reported in the scientific literature and, as far as I knew, never collected. Without having ever seen a specimen of the lizard, my colleagues and I deduced the number and appearance of its chromosomes and the nature of thirty-three of its proteins, each encoded by individual genes on the chromosomes. We also made certain predictions about the lizard's outward appearance, its general behavior, and its distribution.

The predictions were based on genetic studies of two closely related species of tiny, brown, snakelike lizards in the genus *Gymnophthalmus* found in northern South America. One, *G. underwoodi*, had originally attracted our interest because only female specimens had been found. We suspected they were reproducing without males, as do the unisexual whiptail lizards of the American Southwest, species we have been studying for more than twenty years. In the late 1980s, with funding from the National Geographic Society and the National Science Foundation, we proved that *G. underwoodi* does reproduce by parthenogenesis: the females lay eggs that develop without fertilization into another all-female generation.

While studying *G. underwoodi*, my colleagues and I discovered that its body cells did not contain the typical, matching pairs of chromosomes, but instead had two different-looking sets. We also found that many genes coding for specific proteins were present in two slightly different variants. These traits were a sign that the unisexual lizard had a hybrid origin—that is, it was the outcome of a mating between two different, but closely related, species. And like the whiptail lizards we had worked with before, this species was also an all-female clone. (For reasons still unknown, on rare occasions the mixing of genes from two separate species can eliminate the need for male fertilization, resulting in an all-female lineage.)

We quickly realized that each cell in each *G. underwoodi* lizard held all the evidence needed to identify both parent species. Because their sexless system of reproduction produces clones, each individual *G. underwoodi* carries the original combination of chromosomes received from both. We started by comparing chromosomes in a number of closely related lizards. One species, *G. speciosus*, a lizard that also inhabited northern South America, clearly had contributed half of its chromosomes to *G. underwoodi*. The next step was to subtract the known parent's chromosomes from those of the hybrid. This left us with the chromosomes contributed by the other parent, whose identity and outward appearance remained unknown. Similar reasoning allowed us to predict the nature of thirty-three of the missing parent's proteins, even though we had never seen the lizard.

Hoping to find some living representative of the missing parent species, I looked forward to my upcoming field trips to South America. Working in Venezuela, Carol R. Townsend, an associate in the Department of Herpetology at the American Museum, and I collected a variety of lizards for genetic studies in collaboration

A blue-tailed lizard, Gymnophthalmus cryptus, *rests on a leaf in a Venezuelan rain forest.*
Marinus S. Hoogmoed

with Herbert C. Dessauer of the Louisiana State University Medical Center, New Orleans. We needed fresh specimens because preservation in Formalin destroys much of the genetic information in animal tissues, rendering most old museum specimens useless for this kind of research. And because the outward differences among the various species of *Gymnophthalmus* are often slight, we knew that ultimately we would be able to confirm the identity of the other parent of *G. underwoodi* only by examining its genetic makeup. Unfortunately, none of the lizards we collected turned out to be the predicted species.

Although old museum specimens were unsuitable for our genetic studies, I thought they might hold clues to where the missing lizard could be found. I searched the collections of major natural history museums in North America, South America, and Europe for specimens of *Gymnophthalmus* from the Guiana region to borrow and examine. Several specimens turned out to be particularly interesting; they had been collected relatively recently by Marinus S. Hoogmoed, of the National Museum of Natural History, Leiden, and Jose Ayarzaguena, of the Fundación La Salle, Caracas, working independently in the upper drainage of the Orinoco River in southern Venezuela. The collectors noted the overall similarity of these specimens to *G. speciosus* and *G. underwoodi,* as well as one significant difference—a blue tail. The color was no longer visible on the specimens, however; like chromosomes and proteins, colors are often destroyed in preservatives.

After comparing all the available specimens, Hoogmoed, Ayarzaguena, and I decided that these lizards represented an unnamed species, based primarily on the blue tail, the existence of both sexes, and a slight difference in the number of scales around the middle of the body. Because the lizard was so similar to the other two species, especially in preservative, we decided to name it *G. cryptus*. Only future genetic studies on fresh specimens would reveal whether it was the missing lizard, the unknown parent of *G. underwoodi*.

One September, after returning from fieldwork in Arizona, I received a letter from Allan Markezich, an associate professor of biology at Black Hawk College in Illinois (*see* box) who had read our article about the missing lizard. He described a blue-tailed *Gymnophthalmus* he had just collected in southern Venezuela, not far from where the museum specimens of *G. cryptus* had been found. He had live lizards and offered to send me several if I was interested in examining them. Was it possible that the lizards I had hoped to find in a remote area of South America were actually living in Illinois?

In all, four live blue-tailed lizards arrived by mail in New York. In outward appearance, they matched *G. cryptus* in every respect. Townsend and I isolated and photographed the chromosomes of two of them and found that their twenty-two pairs of chromosomes were identical to those predicted for the missing ancestor. So far, so good, but unfortunately, this did not guarantee that they were the same species; in many lizards the appearance of the chromosomes is not distinctive. A comparison of the specific proteins, coded for by individual genes on the chromosomes, would provide better evidence that these lizards were the predicted species.

For this final test, I flew to New Orleans with frozen tissue samples from each lizard. There, Dessauer and I could analyze the proteins. During transport, the tissue samples needed to be kept at temperatures well below freezing. This basically stops physiological activity, including de-

Gymnophthalmus cryptus, I Presume

by Allan L. Markezich

In the spring of 1991, shortly before embarking on a research expedition to investigate the diversity of reptiles and killifish in a remote, rain-forested area of southern Venezuela, I read an article in *Natural History* that described a particularly interesting situation. Charles J. Cole and his colleagues were predicting the existence of a new species of lizard on the basis of the chromosomes and proteins of two other species. I was intrigued because the expedition I was about to embark on was bound for the upper drainage of the Orinoco River, which was within the predicted range of the new lizard.

In early August, Jim Thomerson, an ichthyologist at Southern Illinois University at Edwardsville, and I arrived in the southern state of Amazonas. Moving through the rain forest, Thomerson looked for killifish in flooded inlets adjacent to the bordering savannas, while I scoured the banks for reptiles. Initially our quarries proved scarce. The third day of the expedition was dark and rainy, and our Piaroa Indian guide, Hector Pérez, suggested we journey to a remote area southeast of San Juan de Manapiare, where he thought we would have better luck. Traveling by dugout canoe, we paddled across a broad stretch of flooded savanna until we came to the edge of a dense, virgin rain forest. As we approached, a troop of howler monkeys, apparently disturbed by our arrival, began bellowing, and a two-hour break in the rain ended as we hit the shore.

We entered the forest, its closed canopy sheltering us—and the mosquitoes—from the rain. Moving along the edge, we skirted a forested inlet. While I searched the ground for reptiles, the others waded into the shallow water with fishing nets. Almost simultaneously, Thomerson yelled "fish!" (signaling that he had a killifish in his net) and I heard a faint rustling in the leaf litter at my feet. I quickly brushed aside the leaves, but all I uncovered were more leaves and dirt. Contrary to popular notions about the abundance of reptiles in the rain forests, they usually are scarce; missing one often means missing the only reptile one might encounter for hours. So, even though the disturbance could have been caused by insects, frogs, rodents, or any number of other creatures, I decided to crouch down and wait silently. The strategy worked; near a decaying log two feet away, I heard the rustling again, and a small, snakelike, bronze-colored lizard cautiously appeared from under a clump of brown leaves. With a lunge and a quick grasp, I had the lizard in hand.

The lizard's smooth, glistening skin, its clear, immovable eyelids permanently covering the eyes, and its four toes on each leg were all characteristic of *Gymnophthalmus*. I was particularly intrigued by the blue color on its tail, as no other species with this characteristic had been previously described.

I collected two more specimens that day, and then Pérez guided us to an abandoned adobe hut in a rain forest clearing that had another population of these little lizards. The tiny animals were more difficult to catch here, as they darted into crevices and holes at the base of the hut when we approached.

By the time the expedition was over, we had captured only six of these little lizards, despite having seen dozens in each of the two populations. I wondered if this small sample would be sufficient to answer all the questions we had about the animals, including whether it was the species predicted in the *Natural History* article.

The only way to answer these questions was to get the live specimens back to a laboratory where their chromosomes and proteins could be analyzed. Because *Gymnophthalmus* are very fragile and especially sensitive to dehydration, I decided to transport them in small cotton bags with rain forest leaf litter to provide moisture, shelter, and small invertebrates for food. By putting them in plastic boxes, sheltering them from the sun, and moistening the bags occasionally during the trip, the lizards did quite well; all but one arrived safely in Illinois. I then made two shipments to Cole in New York.

In October 1991, I received from Cole the results of the lizards' protein analysis and a photomicrograph of its chromosomes on which he had scribbled "It is!" I was elated by the discovery and realized that the rain forest, the global cradle of biodiversity, had told us another interesting story. And I wondered, in view of the high extinction rate in these tropical forests, what other such stories may never be told.

Allan L. Markezich is an associate professor in the Department of Natural Sciences and Engineering at Black Hawk College, Moline, Illinois, and a research associate at the Universidad Nacional Experimental de los Llanos Occidentales Ezequiel Zamora in Venezuela.

composition, and holds the enzymes and other proteins in a state of suspended animation. Upon thawing, physiological activity resumes for a while before decomposition begins. If the samples thawed in the transfer, the fragile molecules needed for the study would be lost.

After two weeks in Dessauer's laboratory, we had analyzed proteins representing thirty-two genes, each procedure being an independent test of whether *G. cryptus* was the predicted lizard. We compared each of these proteins with those from *G. underwoodi,* the parthenogenetic hybrid, and *G. speciosus,* its one known ancestor. Of the thirty-two proteins from *G. cryptus,* thirty-one matched the proteins we had predicted for the missing lizard. Because a certain amount of genetic variation is normal in most populations, a single mismatched protein posed no problem. *G. cryptus* is indeed the lizard foretold.

At some time in the past, somewhere in the upper drainage system of the Orinoco River in southern Venezuela, *G. cryptus* mated with *G. speciosus,* a species that ranges from northern South America to southern Mexico. On one or more occasions, the union produced a successful hybrid, *G. underwoodi,* that could reproduce by parthenogenesis. The clone then dispersed along the Orinoco and its tributaries, spread throughout much of the Guiana region, and finally reached some of the southern West Indies.

The case of these diminutive lizards illustrates the power of genetics to unravel complex relationships between species in ways that were impossible about a decade ago. Without detailed genetic studies, distinguishing one species from another and determining the history of their relationships can be difficult or impossible. Does an unusual animal represent a new species or merely a variant of a known one? We also are wondering how many other cryptic species inhabit Amazonia. Few have produced parthenogenetic hybrids to draw our attention to them, as *G. cryptus* did. We may be underestimating the earth's biodiversity. The identification of species is critical because it is the starting point for understanding an organism's role in the ecosystem. Without such knowledge, we cannot begin to know which species are critically important, which are endangered, or which geographic areas are of special importance for conservation.

Charles J. Cole is a curator in the Department of Herpetology and Ichthyology at the American Museum of Natural History.

At the American Museum of Natural History

The American Museum: From History to Legend

This year, the American Museum of Natural History marks its 125th anniversary. Two-hour walking tours of the Museum's halls will take place on Friday, August 12, at 6:00 P.M., and on Saturday, August 13, at 4:00 P.M. The tours will highlight many of the stories behind the Museum's natural history collection, the largest in the world. Free with admission, tours begin in the second-floor Rotunda near the information desk. Call (212) 769-5562.

The Moon and Beyond

Discoveries of black holes, new planets, and colliding galaxies are being documented daily with the help of advanced technologies such as those associated with the Hubble Space Telescope and the Compton Gamma Ray Observatory. The Planetarium's Sky Show, "Update: The Universe," provides current astronomical news and information about the universe. Show times Monday through Friday are 1:30 and 3:30 P.M. On weekends the film will be shown at 1:00, 2:00, 3:00, and 4:00 P.M.

A special exhibition in the Planetarium, "Man on the Moon: The Apollo Adventure," marks the twenty-fifth anniversary of the *Apollo 11* moon landing. The award-winning film, *Eagle Has Landed,* will be shown continuously at the exhibition. Call (212) 769-5900 for information about all Planetarium events.

Africa: The Serengeti

Each year, millions of wildebeests, gazelles, and zebras migrate across seven hundred miles of the Serengeti, the vast savanna ecosystem that straddles two East African countries. A new IMAX film, *Africa: The Serengeti,* will feature the wildlife that inhabit these rich plains, including crocodiles, giraffes, lions, leopards, and elephants. Showtimes are 10:30 and 11:30 A.M. and 1:30 and 3:30 P.M. daily. *Search for the Great Sharks* will continue to be shown at 12:30, 2:30, and 4:30 P.M. daily. For information, call (212) 769-5200.

Baby Belugas

The first surviving beluga whales born in captivity are at New York's Aquarium for Wildlife Conservation. The baby whales, two males and one female, are now three years old and will be the subject of a talk by Louis Garibaldi, the Aquarium's director, on Thursday, August 25, at 7:00 P.M. in the Kaufmann Theater. He will also discuss the approximately 65,000 belugas that roam the arctic waters off Canada, Greenland, and Alaska and will examine some of the tremendous threats to these animals from toxic pollution and subsistence hunting. For ticket availability and information, call (212) 769-5606.

These events take place in the American Museum of Natural History, Central Park West at 79th Street in New York City. The Kaufmann Theater is located in the Charles A. Dana Education Wing. The Museum has a pay-what-you-wish admission policy. For more information about the Museum, call (212) 769-5100.

Roy Chapman Andrews, leader of the Museum's Third Asiatic Expedition to Inner Mongolia, July 1926, collects a young kite.
AMNH

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October 25 - November 12, 1994

Since the time of Marco Polo, the cultural riches and natural wonders of China have intrigued visitors. Lesser known are the riches of neighboring Vietnam. This October, enjoy the spectacular landscapes of rural China and Vietnam and a rare look at other cultures as we travel from Beijing to Hanoi with a team of Museum experts. Among the highlights of our journey are the terracotta soldiers of Xi'an, the Stone forest of Kunming, the lovely Li River and the Red River Valley of Vietnam.

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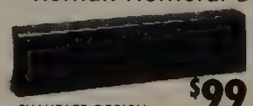

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A Bee in Every Blossom

What's wrong with this picture? The honeybees visiting the blooms of this orchid are dead. In its drive for nectar, each bee has become stuck in a blossom, its thorax tightly wedged into the narrow entrance. The orchid, however, is not carnivorous; the dead bees demonstrate what can go wrong when humans introduce a species into a new part of the world. The orchid *Dendrobium stratiotes* is native to the Moluccas and western New Guinea, where smaller, indigenous bees can easily reach the pool

of nectar within and can back out again to visit other flowers. But once transplanted to Hawaii, where this photograph was taken, the orchid becomes a death trap for the common honeybee, *Apis mellifera,* which is itself foreign to the islands.

Such fatal mismatches between bees and flowers are rare, but not surprising. Flowers and their pollinators have evolved into finely tuned systems in which pollinators are rewarded. Orchids, in particular, have evolved features that attract specific pollinators. This exclusivity may confer a reproductive advantage on plants that are widely scattered throughout a rain forest. Common honeybees, however, will visit almost any flower to steal their reward, and in this case they got caught.—*R. A.*

Photograph by Kjell B. Sandved

AUTHORS

The first underwater wreck that **Daniel J. Lenihan** (page 26) examined in Micronesia was the *Leonora*, the ship of the notorious outlaw Bully Hayes, sunk in 1874 off Kosrae. Side trips to Guam and Truk Lagoon soon had him hooked on the region's World War II remains. Chief of the Submerged Cultural Resources Unit of the National Park Service, Lenihan is based in Santa Fe. He is currently working on projects to identify and preserve American historical sites in foreign waters, as well as on a major survey of shipwrecks in Florida's national parks. For additional reading he recommends *The Liberation of Guam*, by Harry Gailey (Novato: Presidio Press, 1988); *Kosrae: The Sleeping Lady Awakens*, by Harvey Gordon Segal (Federated States of Micronesia: Kosrae Tourist Division, 1989); and *Operation Crossroads: The Atomic Tests at Bikini Atoll*, by Jonathan M. Weisgall (Annapolis: Naval Institute Press, 1994).

In 1962, while an undergraduate at the City College of New York, **Howard Topoff** (page 40) accepted a part-time research position at the American Museum of Natural History. He never left. His undergraduate project, sponsored by the National Science Foundation, was a behavioral and ecological study of army ants. By the time he entered graduate school, his doctoral thesis was half completed. For the next fifteen years, he continued field studies on the social behavior of army ants, first in Panama and then at the Museum's Southwestern Research Station in the Chiricahua Mountains of Arizona. Then an occupational hazard got in the way. "Army ant colonies have tens of thousand of workers," say Topoff, "and it's virtually impossible to study them without receiving multiple stings. Eventually, I developed a sensitivity to their venom, and my reaction to it became progressively worse each year. During my studies of army ants in Arizona, I frequently encountered raids of slave-making ants, and I gradually became fascinated with the questions of how social parasitism evolved. When I learned that slave-making ants in the genus *Polyergus* don't have stingers, I knew it was a done deal." Topoff is currently a professor of psychology at Hunter College of the City University of New York, where he teaches courses in animal behavior. At the American Museum, he is a research associate in the Department of Entomology. For information on the biology and behavior of ants in general, he recommends *The Ants*, by Bert Hölldobler and Edward O. Wilson (Cambridge: Belknap Press, 1990). For a more detailed account of colony takeover by queens of slave-making ants, see Topoff's article in the journal *Animal Behavior*, vol. 46 (1993).

Marine biologist **Tierney Thys** (page 36) is working toward her Ph.D. in the Department of Zoology at Duke University in North Carolina. A native Californian and avid scuba diver since the age of fifteen, she first became interested in molas while diving in Monterey Bay several years ago. "Monterey Bay has a truly exotic assortment of fishes," she says, "not only molas, but opahs and mako sharks appear from the open ocean, while gulper eels, hatchetfish, and dragonfish emerge from the 7,000-foot-deep Monterey Canyon. Add to that gray whales, orcas, sea otters, seals, and sea lions, and you have a marine biologists' heaven." When she's not doing fieldwork during the summers, Thys teaches comparative vertebrate anatomy at Duke and pines for the Pacific. Her photographic collaborator on the mola article, **Mike Johnson,** has spent four years taking pictures of the marine life associated with drift kelp off the coast of southern California. Johnson holds a bachelor's degree in geography from San Diego State University and is working on his master's degree in educational technology.

"I've always loved watching animals, being out of doors, and learning about peoples of other cultures," **Lynne A. Isbell** (page 48) recalls. "But I didn't realize that you could make a career out of that combination of interests until I read Jane Goodall's books about chimpanzees. Then it all came together for me." A native of southern California, Isbell completed her doctorate in animal behavior at the University of California at Davis in 1990. As a student, she was offered the chance to study Amboseli vervets as part of a long-term research project run by husband-and-wife team Dorothy Cheney and Robert Seyfarth at the University of

Pennsylvania. Now an assistant professor in the Department of Anthropology at Rutgers University, Isbell is researching the comparative behavioral ecology of patas and vervet monkeys. She has observed red colobus monkeys at Kibale Forest in Uganda, vervets in Kenya's Amboseli National Park, and patas and vervets in Laikipia, Kenya. When she is not working, Isbell enjoys playing volleyball, soccer, and slow-pitch softball. She also likes training dogs "and generally, just being around them." Three years ago, she married plant ecologist Truman Young. They have a two-month-old son named Peter.

Clive G. Jones (page 56) is a scientist at the Institute of Ecosystem Studies (IES) in Millbrook, New York. There he studies how animals, from little Negev snails to beavers and humans, affect the functioning of their ecosystems, and how environmental stress, in turn, affects them. Another part of his research focuses on the effects of ozone and other forms of air pollution on cottonwood trees, on the chewing and sucking insects that feed on them, and on leaf pathogens. Coauthor **Moshe Shachak**, right, has been studying desert isopods, as well as snails, for nearly twenty-five years. The little, monogamous isopods are so abundant that they account for more biomass than any other animal in the deserts of North Africa. As they turn over and aerate the soil, they fill much the same role that earthworms do in moister climates. Shachak is an associate professor at Ben Gurion University, the Blaustein Institute for Desert Research, in Sede Boqer, Israel, and an adjunct associate scientist at IES. He is also interested in the ecology of desertification. Normally an underwater photographer, **Jeffrey L. Rotman**, says the snail assignment was "a breath of fresh air," although it meant getting going very early in the morning, while the desert rocks were still covered with dew. Originally from Boston, Rotman has lived in Israel for fifteen years, but he travels all over the world on his mostly watery assignments. For more on these subjects, readers might turn to *Linking Species and Ecosystems*, edited by Jones and John Lawton (New York: Chapman and Hall), which is due out this month. A general treatment of how species affect ecosystems can be found in "Organisms as Ecosystem Engineers," by Jones, Lawton, and Shachak, published this year in the journal *Oikos* (69:373–86).

The photographer of this month's "Natural Moment" is **Kjell B. Sandved** (page 74). A native of Norway, he started as a publisher, producing encyclopedias of art and music. In 1960, Sandved arrived at the Smithsonian Institution's Museum of Natural History, intending to spend six months researching and collecting photographs for his next work, an encyclopedia of animals. He was so captivated by the museum's vast collections and exhibits that he became a volunteer there and hasn't left yet. Never having taken a photograph before starting at the museum, he began teaching himself nature microphotography by trial and error. After two years he joined the museum's staff as a "scientist aide photographer" and became the institution's only nature photographer and filmmaker. Working on his own book projects, Sandved has traveled around the world. One of his most popular creations was his "butterfly alphabet," a poster with each letter and Arabic numerals 0 through 9 formed by the naturally occurring patterns of the scales on butterfly wings. After twenty years spent examining the wings of uncounted numbers of butterflies and moths around the world, Sandved finally found all the letters he needed. To photograph the orchid and bees in this issue, Sandved used a Nikon camera with bellows and Zeiss Luminar lenses.

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